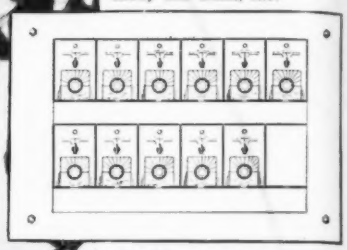
TECHNOLOGY DEPT.

TECHNOLOGY REVIEW

April 1952

PUBLIC LIBRARY
APR 14 1952
DETROIT

The Travelers Insurance Co. Buildings, Hartford, Conn. Architects: Voorhees, Walker, Foley & Smith. Consulting Engineers: Meyer, Strong and Jones. Heating Contractor: Libby and Blinn, Inc.



This 11-zone panel centralizes control at one point. Any zone may be (a) shut off, (b) put on automatic or (c) put in heating-up position from this point. Rate of heat to any zone may be speeded up or slowed down in comparison with the normal supply as indicated by Outdoor Thermostat control.

Heating Modernization Program Pays The Travelers Insurance Company

The original home office building of The Travelers Insurance Company was built in 1906. As The Travelers grew, additional office space was provided by new buildings erected in 1912, 1918 (the Tower building), 1921 (the building in center foreground), 1926, 1928 (the large rectangular building at right), 1938 and 1939, bringing the total floor area occupied by the Company to 1,012,834 square feet.

In 1944, 38 years after the original heating installation, The Travelers asked their architects to recommend the changes necessary for modern heating with two objectives—minimum fuel cost and complete comfort for all employees.

After careful study, the following were approved: (1) four new oil-fired water-tube boilers with automatic combustion control, each boiler having a capacity of 25,000 lbs. of steam per hour, (2) a smaller water-tube boiler for heating domestic hot water in the summer months, new vacuum pumps and related boiler-room equipment, (3) improvements to the existing ventilation system, (4) a Webster Moderator System of Steam Heating for "Controlled-by-the-Weather" economy.

By 1948, when the modernization program was completed, heating service was noticeably improved. Employee comfort was definitely improved as chronic heating complaints had been eliminated. Labor costs were reduced.

Actual fuel savings of approximately 40% were indicated by a comparison of heating costs between the operation of the old coal fired plant and heating system, and the new boiler plant along with the new Moderator controlled heating of the buildings.

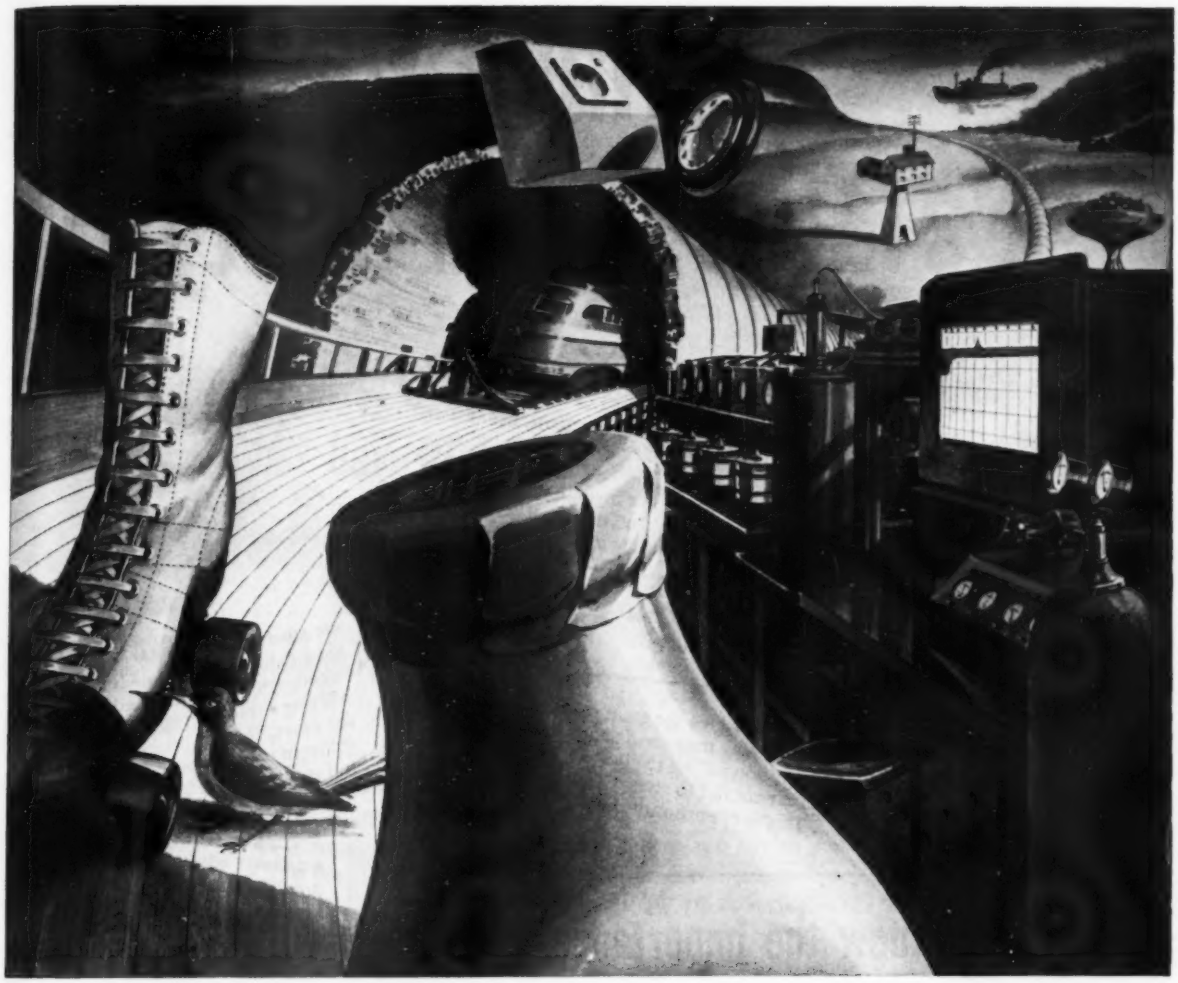
Here is evidence that well-planned heating modernization programs pay big dividends in improved heating service and lower fuel costs. If you are planning the heating for a new building or modernization of an existing building, the Webster Moderator System belongs in your plans.

There are Webster representatives in 65 principal cities working with architects, engineers and heating contractors in the application of Webster Systems and Equipment. Call your Webster representative or write us for his name.

Address Dept. TR-4

WARREN WEBSTER & CO.
Camden 5, N.J. Representatives in Principal Cities
In Canada, Darling Brothers, Limited, Montreal

WEBSTER
MODERATOR
SYSTEM
OF STEAM HEATING
"Controlled by the weather"



All but one of the objects in this picture have something in common — Norton or Behr-Manning abrasive products are vital factors in their manufacture and in their quality. ***Can you find the stranger?***

What doesn't belong in this picture?

The skating rink? No! The rink was machine sanded by Behr-Manning Resinized Speed-Grits Floor Sanding Paper. Roller skates, too, get smooth-running, long-wearing qualities from operations involving Behr-Manning and Norton abrasive products.

The research lab? No! ALUNDUM refractory laboratory ware in a variety of sizes and shapes is widely used in laboratory work for operations involving incineration, filtration and aeration.

The clock? No! Many of its parts are deburred and finished by means of Norton ALUNDUM Tumbling Abrasive.

The milk? No! Practically every piece of modern dairy equipment depends on Norton and Behr-Manning products for its manufacture and maintenance.

The street car, the washing machine, the bon-bon dish also owe a large part of their existence to Norton and Behr-Manning products used during manufacture.

The stranger in the picture is the robin. Any man-made product — whether of metal, wood, paper, cloth, leather, ceramics, plastics — depends in some important way on products that bear such well-known trademarks as Norton and Behr-Manning.

Norton Company** makes abrasives, grinding wheels, refractories, Norbide grain and molded products, grinding and lapping machines, non-slip floors.* ***Norton Company, Main Office and Works, Worcester 6, Massachusetts.

Behr-Manning** makes abrasive paper and cloth, oilstones, abrasive specialties, Behr-Cat brand pressure-sensitive tapes.* ***Behr-Manning Corporation, Division of Norton Company, Troy, New York.

SOLD BY LEADING DISTRIBUTORS AND DEALERS THE WORLD OVER

NORTON BEHR-MANNING

NORTON COMPANY BEHR-MANNING

WORLD'S LARGEST MANUFACTURERS OF ABRASIVES AND ABRASIVE PRODUCTS

MAKING BETTER PRODUCTS TO MAKE OTHER PRODUCTS BETTER

THE TECHNOLOGY REVIEW, April, 1952, Vol. LIV, No. 6. Published monthly from November to July inclusive at Emmett Street, Bristol, Conn. Publication date: twenty-seventh of the month preceding date of issue. Annual subscription $3.50; Canadian and Foreign subscription, $4.00. Entered as second-class matter December 23, 1949, at the Post Office at Bristol, Conn., under the Act of March 3, 1879.

Have You Taken This Opportunity for

COLONEL, RESEARCH AND DEVELOPMENT DIVISION, DEPARTMENT OF THE ARMY: "Full support should be given any sound measure designed to encourage inventors and facilitate consideration and further development of their ideas or inventions. It is difficult to conceive of any action that would accomplish more in this direction than that called for in the Sinclair Plan."

CABINET MEMBER: "It should bring to light some valuable ideas which might otherwise not have been known."

AN INVESTMENT COUNSELOR: "I can imagine the great surge of hope now going through the breasts of the young men specializing in this field. 'Here,' they will say, 'is a corporation willing to give us a break.' . . . Its fundamental unselfishness cannot fail to strengthen the faith of those without property. . . . This is opportunity!"

AN AIR FORCE GENERAL: "I have read of your plan for encouraging invention and offering a testing ground for ideas. Such a project seems to me both practical and inspirational!"

Men Who Know the Importance of Independent Invention Encourage You to Use the Sinclair Plan

A CABINET MEMBER: "The provisions regarding patents are unique . . . the compensation for your investment of money, time, and facilities would be limited to nonexclusive, royalty-free shop rights for your company."

A MEMBER OF THE JOINT CHIEFS OF STAFF: "The Sinclair Oil Corporation is performing another fine public service in opening its research laboratories to the American inventor. I am confident that the nation will derive many benefits from this selfless service."

PRESIDENT OF A BROADCASTING NETWORK: "To make the magnificent facilities of the Sinclair Research Laboratories available to inventive Americans under what would seem to be a very fair arrangement is a constructive and forward-looking step."

PRESIDENT OF LARGE MANUFACTURING CORPORATION: "We all think the plan, which opens wide the doors of your great research laboratories, should indeed encourage individual inventors."

AN AIR FORCE GENERAL: "I wholeheartedly agree that there is a need to help the independent inventor because of the complexity of modern technology and the prohibitive cost of these facilities. Your farsighted plan is a great stride in relieving this situation."

PRESIDENT OF A LARGE MANUFACTURING COMPANY: "You have recognized a great need, and have done something objective to overcome it . . . another idea which puts to beneficial use the resources and capacity of a large group."

Advantage of Independent Inventors?

If you have an idea for a new petroleum product— but do not have the facilities needed to develop it— the Sinclair Plan offers you laboratory help.

EIGHT months ago, Sinclair opened up a part of its great research laboratories to independent inventors who had ideas for new or improved petroleum products but who did not have the facilities needed to develop and profit by their ideas.

To date nearly 5,000 inventive people have submitted ideas to the laboratories; and the Sinclair Plan has become recognized as a service to inventors, the oil industry and the public. As a result we have made the Plan part and parcel of the long-range operation of our company.

If you have an idea for a new or improved petroleum product or application, you are invited to submit it to the Sinclair Research Laboratories. In your own interest, each idea must first be protected by a patent application or a patent.

If the laboratories select your idea for development, they will make a very simple arrangement with you: In return for the laboratories' work, Sinclair will receive the privilege of using the idea for its own companies, free from royalties. This in no way hinders the inventor from selling his idea to any of the hundreds of other oil companies for whatever he can get. Sinclair has no control over the inventor's sale of his idea to others, and has no participation in any of the inventor's profits through such dealings.

HOW TO PARTICIPATE: Instructions are contained in an Inventor's Booklet. Write to W. M. Flowers, Executive Vice-President, Sinclair Research Laboratories, Inc., 600 Fifth Avenue, New York 20, N. Y.

IMPORTANT: *Please do not send in any ideas until you have sent for and received the instructions.*

Nine buildings of the Sinclair Research Laboratories at Harvey, Ill.

SINCLAIR—for Progress

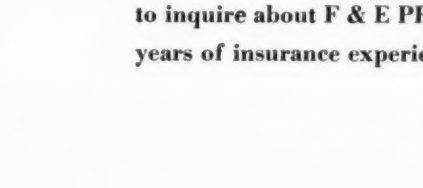
FAIRFIELD & ELLIS

1902 *Fiftieth Anniversary* 1952

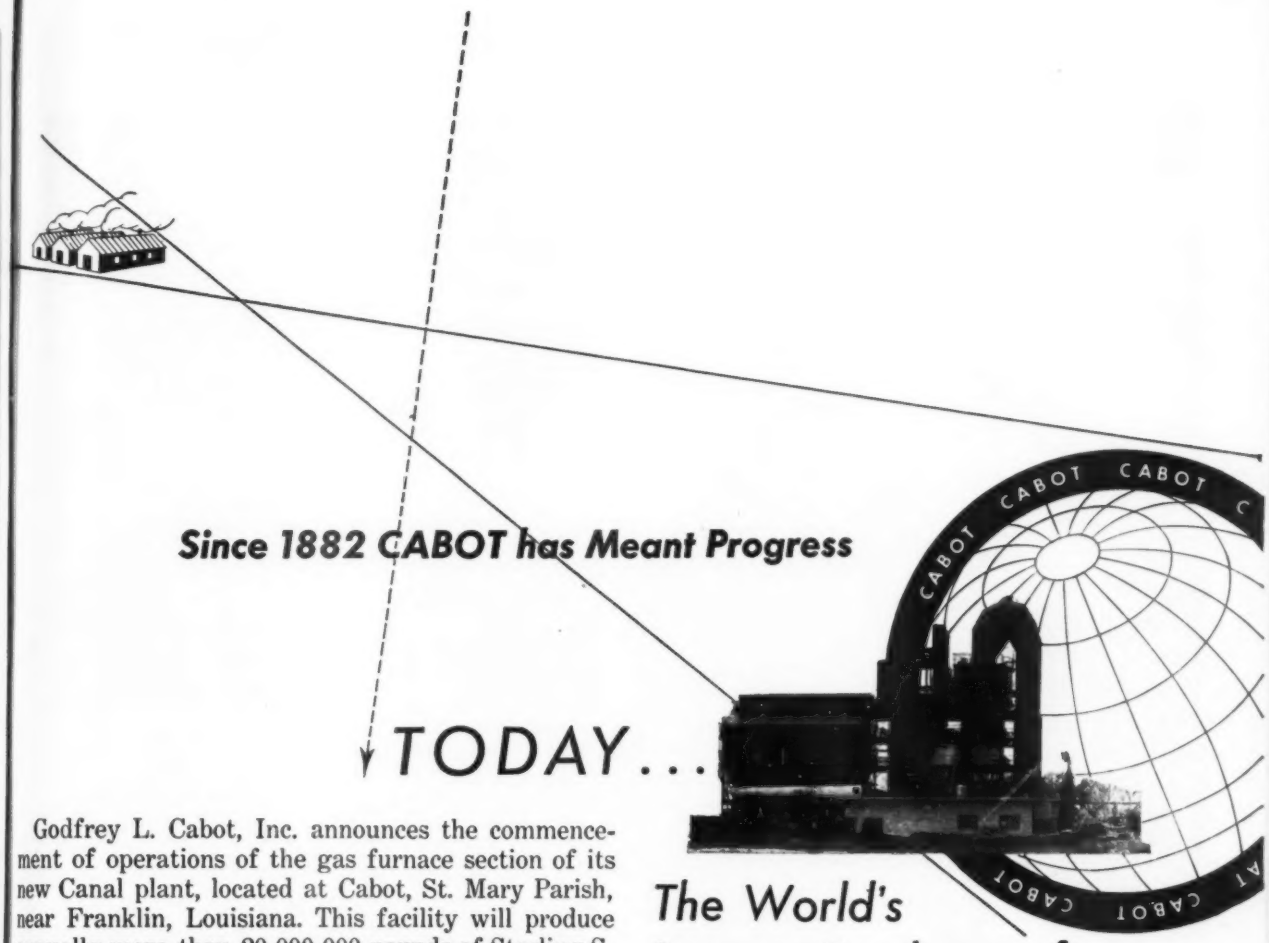
"Look Ahead In All Kinds of Weather"

Have You Adjusted Your Insurance To TODAY'S VALUES?

Time to take new bearings? Time to check all your insurance policies? Time to make your coverage realistic in the face of new values, new conditions, new laws, new regulations? . . . Why not take time today to inquire about F & E PROJECTED SECURITY, based on forty-nine years of insurance experience of the first rank.



Fairfield & Ellis
INSURANCE
BOSTON
NEW YORK
MONTREAL



Since 1882 CABOT has Meant Progress

TODAY...

The World's Largest Producer of Carbon Blacks Opens Another New Plant

Godfrey L. Cabot, Inc. announces the commencement of operations of the gas furnace section of its new Canal plant, located at Cabot, St. Mary Parish, near Franklin, Louisiana. This facility will produce annually more than 20,000,000 pounds of Sterling S, uniform high quality semi-reinforcing furnace black, used in the production of a wide range of rubber products.

Operation of this new producing unit marks another major step in the Cabot program to assure the constant availability of adequate supplies of all types of carbon black essential to industry. The Cabot Companies are now producing SRF black at Guymon, Oklahoma; Pampa, Texas; and Ville Platte, Louisiana. This new plant, located on the Gulf Intracoastal Waterway, and on the Texas and New Orleans branch of the Southern Pacific Railroad, is fourth in a series of SRF plants independently established to accomplish our objective. Each plant is a separate source of supply of the same, uniform high quality SRF black, and employs the use of different truck and railroad services.

These additional facilities will insure further customer protection against production curtailments of every kind, making possible even better Cabot service.

GODFREY L. CABOT, INC. CABOT

77 FRANKLIN ST., BOSTON 10, MASS.

How would YOU control costs here?

ECONOMY IN TEA BAG PRODUCTION is aided by accurate temperature control. Leading tea companies use Pneumatic Scale Corporation's machine, which forms material into bags, feeds in tea, seals bags with heat and pressure, cuts them apart and tags them. A simple, inexpensive Fenwal THERMOSWITCH® thermostat provides the exact temperature control required for effective, trouble-free sealing.

IRONING COMFORT INTO SHOES is a time- and money-saving operation with Compo's "Lining Smoother." This heated metal form is placed inside a shoe and spread open, to smooth wrinkles out of the lining. For the precise temperature control needed to avoid both scorching and inadequate ironing, a Fenwal THERMOSWITCH unit provided the most satisfactory, lowest-cost solution.

A FENWAL THERMOSWITCH CONTROL may cut your costs, too. Its external, single-metal shell expands or contracts *instantly* with temperature changes, making or breaking enclosed electrical contacts. Compact, highly resistant to shock and vibration, Fenwal THERMOSWITCH units have solved hundreds of problems.

SEND FOR THIS NEW CATALOG for complete explanation of the unique THERMOSWITCH unit. Also ask for more detailed, illustrated discussions of the problems above. Fenwal engineers will be glad to help you solve your temperature control problems involving heat, humidity, radiant heat, pressure and other variables. Write Fenwal, Incorporated, Temperature Control Engineers, 94 Pleasant Street, Ashland, Massachusetts.

Fenwal

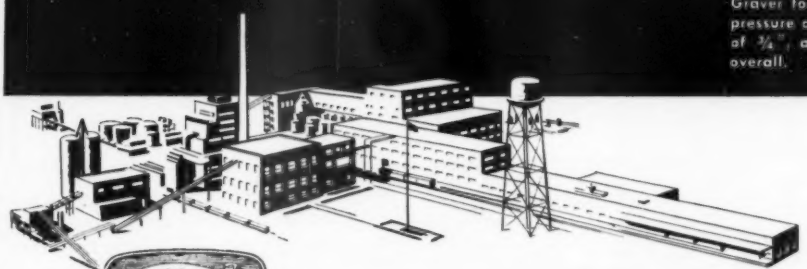
THERMOSWITCH®

Electric Temperature Control and Detection Devices

SENSITIVE . . . *but only to heat*

GRAVER builds
5 Stainless-Clad Digesters–

One of the five stainless clad digesters fabricated by Graver for the Riegel Corporation. Built for working pressure of 126 PSI, each has a total shell thickness of ¾", an inside diameter of 11', and stands 48' overall.



RIEGEL'S PAPERS
SINCE 1862

A leader in paper making since 1862, the Riegel Corporation produces more than 600 different kinds of paper, with glassine and greaseproof papers its largest lines. The recent addition of a pulp mill permits Riegel to integrate its every operation from tree to finished paper.

for New Riegel Pulp Mill at Acme, North Carolina

The vital part these five digesters play in Riegel's new pulp mill demanded fabrication of the highest order. Top efficiency, long, dependable service, and minimum down-time were "musts". By intensive research and painstaking fabrication, Graver's goal was not only the fulfilling of these requirements, but in addition the elimination of other operating problems inherent in the usual digester. These very real evidences of Graver ability are worth remembering whenever fabrication in steel or alloys is *your* need.

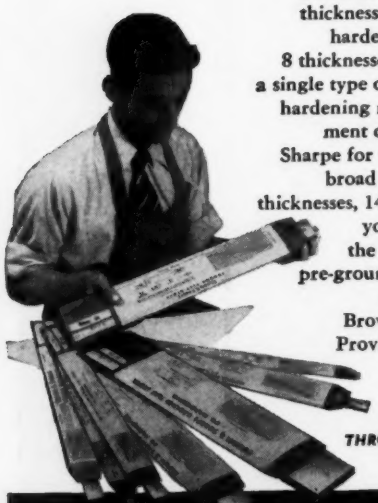
GRAVER TANK & MFG. CO., INC.
EAST CHICAGO, INDIANA
NEW YORK • CHICAGO • PHILADELPHIA • DETROIT • WASHINGTON
CINCINNATI • CATASAUQUA, PA. • HOUSTON • SAND SPRINGS, OKLA.

GRAVER

GROUND FLAT STOCK

In Complete Range of sizes for Oil or Water Hardening

You'll find Brown & Sharpe Ground Flat Stock available in all the convenient sizes up to 1" thickness for either oil or water hardening. Moreover, in the 8 thicknesses from 1/64" to 3/16" a single type of stock serves for *both* hardening methods . . . a development originated by Brown & Sharpe for your convenience. The broad selection of sizes — 16 thicknesses, 145 sizes in all — allows you to utilize more fully the economies of accurate, pre-ground flat stock. Write for complete information. Brown & Sharpe Mfg. Co., Providence 1, R. I., U. S. A.



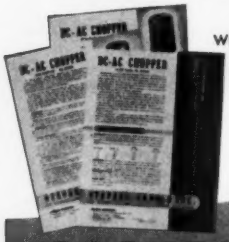
WE URGE BUYING THROUGH THE DISTRIBUTOR

BROWN & SHARPE

DC-AC CHOPPER

A model for every use — 60 and 400 cycles Single pole and double pole — Make-before-break contacts — Contacts in air or in liquid

These Choppers convert low level DC into pulsating DC or AC, so that servo-mechanism error voltages and the output of thermocouples and strain gauges may be amplified by means of an AC rather than a DC amplifier. They are hermetically sealed, precision vibrators having special features which contribute to long life and low noise level.



WRITE FOR CATALOGS . .
#246B, 60 cycles, AC
#280, 400 cycles, AC

STEVENS-ARNOLD
INCORPORATED
22 ELKINS STREET, SOUTH BOSTON 27, MASS.

THE TABULAR VIEW

Co-operative Effort. — The beneficial effects of science cannot be maximized through science alone. The co-operation of many others is needed for this achievement as PROFESSOR THOMAS K. SHERWOOD, '24, Dean of Engineering at the Institute, reminds us in his article (page 295), first given at the symposium on "Frontiers in Science" at the alumni meeting in Los Angeles on January 26. Dean Sherwood received the bachelor of science degree from McGill University in 1923. From M.I.T. he received the S.M. and Sc.D. degrees in 1924 and 1929, respectively. From 1928 to 1930 he was assistant professor of chemical engineering at Worcester Polytechnic Institute. He returned to M.I.T. in 1930 and since 1946 has been dean of engineering at the Institute.

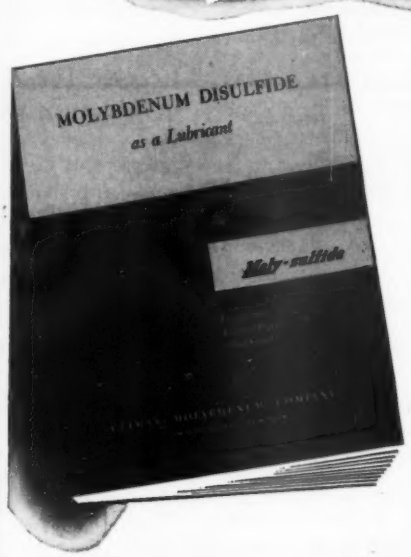
Sound Design. — Since the end of World War II, interest in high-quality audio-reproducing systems for the home has increased by leaps and bounds, as is recounted (page 297) by C. J. LEBEL, '26. Mr. LeBel received the S.B. and S.M. degrees from the Institute in 1927. In 1937 he became chief engineer of Audio Devices, Inc., and is now vice-president of this firm which is the largest producer of lacquer-recording blanks. Mr. LeBel is also chief engineer of Audio Instrument Company, Inc., which firm has pioneered in a number of new electronic instruments. In presenting "Audio Engineering Comes into the Home" Mr. LeBel has been primarily concerned with removing the technicalities of his field for the general reader.

Conversationally Speaking. — Some unexpected problems arise when the Institute undertakes to provide adequate telephone facilities for the 5,000 members of its Faculty and staff, in addition to its 5,000 students. The Institute's present telephone facilities are described (page 302) by PROFESSOR CARLTON E. TUCKER, '18, who planned the present installation with Bell System engineers. Since receiving the S.B. degree from the Institute in 1918, Professor Tucker has spent his entire professional career at Technology. During World War II he was appointed executive officer for the Department of Electrical Engineering, and also directed the M.I.T. Radar School which trained many officers for the armed services.

Dollars and Sense. — With both practical and theoretical understanding of the field, PROFESSOR RALPH E. FREEMAN, Head of the Department of Economics and Social Science, writes with unusual understanding of the Institute's aim in offering courses in economics (page 304). Professor Freeman is a graduate of McMaster University in Canada and winner of a Rhodes Scholarship. He carried on graduate studies at Balliol College, Oxford, and spent two years at the University of Chicago where he was awarded a fellowship in the Department of Economics. He became associate professor of economics at M.I.T. in 1931 and head of the Department of Economics and Social Science in 1933.

If you want authoritative information on *Moly-sulfide* as a lubricant

Write for this booklet



Climax Molybdenum Company
500 Fifth Avenue New York City

Please send your FREE *Booklet*
"MOLYBDENUM DISULFIDE AS A LUBRICANT"
BLOCK LETTERS PLEASE

Name .....

Position.....

Company .....

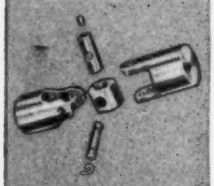
Address.....

TR-4

Fewer Parts make easy assembly

Simple construction, fewer parts make assembly and disassembly easy — also mean longer life.

CURTIS UNIVERSAL JOINTS



Simple construction is not the whole story. A combination of modern design, wise choice of alloy steels, with a special heat treatment for each part, give greater strength with less weight. And you can depend on Curtis catalog ratings — they are based on hundreds of actual tests.

ONLY CURTIS OFFERS ALL THESE ADVANTAGES

Availability — 14 sizes always in stock.

Simplicity — fewer parts, simpler construction.

Government Tests — complete equipment for government tests in our plant.

Write today for free engineering data and price list

CURTIS UNIVERSAL JOINT CO., INC.

8 Birnie Ave. Springfield, Mass.

As near to you as your telephone

A MANUFACTURER OF UNIVERSAL JOINTS SINCE 1919

BEFORE PRODUCTION . . .

Gear design for industry or functioning device can foretell profit or loss.

Before production plans go too far—be sure you know what you can save by buying gears especially engineered for your exacting needs.

Diefendorf builds gears of all sizes and types and all materials to B.P. specs only.

DIEFENDORF GEAR CORP.

Syracuse, New York

DIEFENDORF GEARS

MAIL RETURNS

Allegiance Shared

FROM E. H. CAMERON, '13:

As a proud member of the fifth class to graduate from the Lowell Institute School for Industrial Foremen, in 1909, may I express my appreciation of the splendid article in the December, 1951, issue of The Review by Arthur L. Townsend on "The Lowell Institute School."

Like all youngsters, I took for granted the fact that some good person had made possible this fine education at practically no cost at all. Professor Townsend's article gives the historical background of the century-old Lowell Trust, from which the Foremen's School stems. It shows how a man, over 100 years ago, recognized the determined urge of most young men to get an education, and who was wise enough to write a will that has met the needs of such men.

There exists a mutual advantage between M.I.T. and Lowell Institute in this matter. Townsend's article tells how the Lowell Trust played an important part in the establishment of M.I.T. The concomitant obligation of Lowell to M.I.T. is that, consistent with the spirit of the will, M.I.T.'s laboratories and staff are available to Lowell students.

Superior administrative talent has been necessary to carry on the Lowell project with such mutual advantage to both institutions. The greatest beneficiary, of course, is the Lowell student body. They are screened men, who are getting their education the hard way, and who will continue to study. Some continued their education by matriculating at M.I.T. after graduating from Lowell. Statistics would be interesting stating the number of men who are graduates of both Lowell and M.I.T.

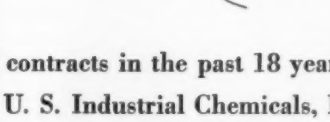
Boston, Mass.

In Step

FROM DR. EGON E. KATTWINKEL, '23:

May I compliment you on the January, 1952, number of The Review. The photography is unusually interesting with reproductions excellent. For some years now I have been increasingly proud to place the issues on my waiting room magazine table. The Review is right in step with the new spirit of the humanities which pervades the Institute. More power to you!

West Newton, Mass.



8 contracts in the past 18 years for U. S. Industrial Chemicals, Inc.

Evidence of quality, low cost and speed.

W. J. BARNEY CORPORATION

FOUNDED 1917

101 PARK AVENUE, NEW YORK

INDUSTRIAL CONSTRUCTION

Alfred T. Glassett, '20, President

Power at your finger tip

Nearly everything you do today is done easier, quicker and better—thanks to electricity

If you are an average American worker you use the strength of nine horses each working hour of the day.

WHERE DO YOU GET SUCH POWER—Merely by flicking a switch . . . for by that simple act you are tapping the vast sources of electric energy that are ready to work for all of us in the home and on the job.

Today, the use of electric power has grown to where a single factory uses more electricity than an entire city used a generation ago. And your home—with its electric appliances, lighting and other conveniences—consumes more power than was used in yesterday's factory.

NEW MATERIALS WERE NEEDED—This great progress could not have been achieved without the many new and better materials which make possible today's larger and more efficient power generating equipment.

A JOB FOR ALLOY STEEL—Giant turbines and generators, for example, couldn't stand up under terrific heat, pressure, wear and corrosion if it weren't for steels made tough and enduring by alloying metals.

Improved plastics also do their part in better insulation and protective coatings. And carbon brushes are as vital to huge generators as they are to your vacuum cleaner motor.

FOR MORE POWER—Developing and producing alloys, plastics, carbons and many other better materials for our power industry are but a few of the many ways in which the people of Union Carbide serve all of us.

STUDENTS and STUDENT ADVISERS

Learn more about the many fields in which Union Carbide offers career opportunities. Write for the free illustrated booklet "Products and Processes" which describes the various activities of UCC in the fields of ALLOYS, CARBONS, CHEMICALS, GASES, and PLASTICS. *Ask for booklet A-2.*

UNION CARBIDE
AND CARBON CORPORATION
30 EAST 42ND STREET UCC NEW YORK 17, N. Y.

UCC's Trade-marked Products of Alloys, Carbons, Chemicals, Gases, and Plastics include

ELECTROMET Alloys and Metals • HAYNES STELLITE Alloys • NATIONAL Carbons • ACHESON Electrodes • PYROFAX Gas • EVEREADY Flashlights and Batteries BAKELITE, KRENE, and VINYLITE Plastics • PREST-O-LITE Acetylene • LINDE Oxygen • PRESTONE and TREK Anti-Freezes • SYNTHETIC ORGANIC CHEMICALS

Goodyear announces the New LifeGuard Safety Tube!

BLOWOUT-SAFE! PUNCTURE-SAFE!

Only the LifeGuard principle gives you positive safety in any blowout!
1 Blowout-safe! Only a double air chamber gives positive safety in a blowout emergency. If outer chamber blows out, LifeGuard inner chamber still holds enough air to allow you to come to a safe, controlled, straight-line stop.
2 Puncture-safe! Goodyear puncture-sealant (a layer of gum rubber) flows into hole, seals puncture without loss of air.
3 Re-usable! New LifeGuard Safety Tubes can be re-used in at least three sets of tires for 100,000 miles or more.

The only 100,000-mile re-usable protection! You save 20% to 43% per wheel!

No longer need you worry about the danger of blowouts or the inconvenience of punctures!

The New LifeGuard Safety Tube gives you not just partial protection, but actually makes a blowout harmless, seals its own punctures.

And it's re-usable! This is the *only* blowout and puncture protection that *doesn't wear out when your tire wears out!*

Figure the savings yourself: you need to buy a set of the New LifeGuard Safety Tubes only once in 100,000 miles. You spread the cost over *three or more sets of tires.* Thus you save 20% to 43% per wheel. And these New LifeGuard Safety Tubes by Goodyear hold air more than 5 times longer than natural-rubber tubes.

See your Goodyear dealer today! Get the complete story of re-usable blowout and puncture protection. The kind of *practical* protection every motorist can afford!

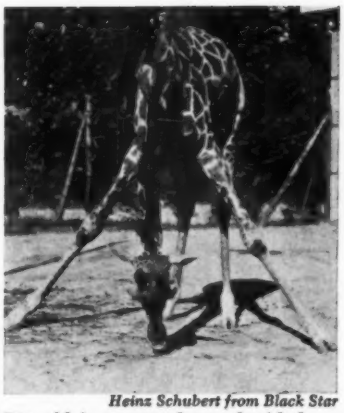
Only multi-million-mile proved protection! In 17 years, in millions of miles, we know of no case of failure of the LifeGuard principle in a blowout.

You can use New LifeGuards in your present tires! If your tires are still good, just get your Goodyear dealer to equip them with a set of New LifeGuard Safety Tubes. You can use them in at least three sets of tires.

NEW LIFEGUARD SAFETY TUBES

by GOODYEAR

LifeGuard, T. M.—The Goodyear Tire & Rubber Company, Akron, Ohio



Heinz Schubert from Black Star

"Wouldn't you just know they'd slip a decimal point in Structures."

THE TECHNOLOGY REVIEW

TITLE REGISTERED, U. S. PATENT OFFICE

EDITED AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

CONTENTS *for April, 1952*

Vol. 54, No. 6

DINGHIES ON THE CHARLES RIVER • *Photograph by Laurence Lowry* — THE COVER

STATUE OF MINUTE MAN, CONCORD, MASSACHUSETTS • *Photograph by Raymond E. Hanson* ..... FRONTISPIECE 290

NEW FRONTIERS IN SCIENCE ..... By THOMAS K. SHERWOOD 295
Co-operative teams of technologists, with each man contributing his share to make the whole equal to more than the sum of its parts, advance progress in science

AUDIO ENGINEERING COMES INTO THE HOME .... By C. J. LEBEL 297
The application of good engineering principles to audio systems has resulted in meteoric rise in the sale of sound systems for home use

TELEPHONE SERVICE FOR THE INSTITUTE .. By CARLTON E. TUCKER 302
One of the largest private branch switchboards in New England is required to meet the Institute's internal communication requirements

ECONOMICS AT M.I.T. ..... By RALPH E. FREEMAN 304
Diversity of views helps develop a sound approach for solving problems in fields where data may be inadequate

THE TABULAR VIEW • *Contributors and Contributions* 284

MAIL RETURNS • *Letters from Review Readers* 286

THE TREND OF AFFAIRS • *News of Science and Engineering* 291

THE INSTITUTE GAZETTE • *Relating to the Massachusetts Institute of Technology* 307

Editor: B. DUDLEY

Business Manager: R. T. JOPE

Circulation Manager: D. P. SEVERANCE

Editorial Associates: PAUL COHEN; J. R. KILLIAN, JR.; WILLY LEY; F. W. NORDSIEK; J. J. ROWLANDS

Editorial Staff: RUTH KING; BEATRICE D. WRIGHT

Business Staff: EILEEN E. KLIMOWICZ; MADELINE R. MCCORMICK

Publisher: H. E. LOBDELL

Published monthly from November to July inclusive on the twenty-seventh of the month preceding the date of issue, at 50 cents a copy. Annual subscription, $3.50; Canadian and foreign subscription, $4.00. Published for the Alumni Association of the M.I.T.: Alfred T. Glassett, President; H. E. Lobdell, Executive Vice-president; Hugh S. Ferguson, Allen Latham, Jr., Vice-presidents; Donald P. Severance, Secretary-Treasurer. Published at Hildreth Press, Inc., Bristol, Conn. Editorial Office, Room 1-281, Massachusetts Institute of Technology, Cambridge 39, Mass. Entered as second-class mail matter at the Post Office at Bristol, Conn. Copyrighted, 1952, by the Alumni Association of the Massachusetts Institute of Technology. Three weeks must be allowed to effect change of address, for which both old and new addresses should be given.

Raymond E. Hanson

By the rude bridge that arched the flood,
Their flag to April's breeze unfurled,
Here once the embattled farmers stood,
And fired the shot heard round the world.

— Ralph Waldo Emerson

THE
TECHNOLOGY
REVIEW

Vol. 54, No. 6 April, 1952

The Trend of Affairs

What's New in Electronics

WHAT was probably one of the largest assemblages of engineering talent on record gathered in New York City on March 3 to 6, inclusive, for the annual national convention of the Institute of Radio Engineers. In celebration of its 40th anniversary, the I.R.E. presented a technical program of well over 200 engineering papers at the Waldorf Astoria Hotel, with overflow symposia at the Belmont Plaza Hotel. In addition to the technical program, the four floors of the Grand Central Palace were crowded to capacity with exhibits of equipment for the electronics field. The 29,500 engineers who were registered for the four-day event were also subjected to a highly active, employment-solicitation campaign by firms who had – or hoped to get – their share of orders in today's research and development program which, for the current year, is expected to cost three billion dollars.

Many of the symposia and discussion groups dealt with progress in electronic instruments, radio antennas, transmitters and receivers, television, and electric circuits as would be expected in meetings of radio engineers. But, perhaps one fifth to one quarter of the technical papers were devoted to topics which, a decade back, would have been regarded as lying outside the normal sphere of activities for radio engineers. Such is the case, for example, with the meetings which were devoted to transistors, feedback control, information theory, medical electronics, telemetering, digital computers, magnetic core memory devices, and circuits employing ferroelectric and ferromagnetic materials.

Having its initial stimulus in the groundwork laid during World War II by Professor Norbert Wiener of the Department of Mathematics and his associates at Technology, information theory is basically rather mathematical. Its principles cannot be easily or quickly interpreted in layman's terms, although progress in this field brings to light engineering applications which all can appreciate. Because of recent progress in this field, it is possible to produce communication systems which are freer from noise interference than formerly. Moreover, physical facilities (such as wire lines or radio channels) can now be used much more effectively than in the past. By extending the amount of useful information which can be transmitted over given physical facilities, we may look forward to improvements in the performance of communication systems, or possibly, to reduction in cost of services of specified quality.

New fields of engineering application are rapidly being developed as an outgrowth of fundamental studies in physics of the solid state. Devices employing semiconductors, or the ferroelectric or ferromagnetic properties of materials, are especially promising. Unique nonmetallic materials, called ferrites, exhibit new combinations of magnetic, conducting, and dielectric properties whose intriguing possibilities are just now being investigated. With piezoelectric properties and high dielectric constants, another group of materials, called titanates, have been employed as compact electric-circuit elements in air-borne equipment, or as mechanisms for converting electric energy to mechanical energy and vice versa. Amplifiers and oscillators of unusual types and new kinds of memory and switching circuits have already been devised (or may soon be expected to appear) as properties of ferroelectric and ferromagnetic materials are intelligently applied. In the field of semiconductors, perhaps the outstanding development is the transistor whose versatility, compactness, ruggedness, long life, and low-power consumption threaten the ordinary electron tube with serious competition in a wide range of applications.

Already, rapid progress has been made in electronics through development of new materials having specified arrangement of atoms and molecules. In our contemporary technology, it should be but a small step for the design engineer of the future to obtain, on specification, materials with the required physical, chemical, metallurgical, electrical, piezoelectric, and magnetic properties. In the reasonably

near future, there may be an important field of employment for those scientists and engineers who are able to shape the elements into compounds of desired properties. The fact that William Shockley, '36, was awarded the Morris Liebman Memorial Prize by the I.R.E. for his contributions to the creation and development of the transistor is a straw in the wind. But, universities may find it desirable to still further promote progress of this kind, through establishment of courses of instruction for the training of others who can design materials – as well as products – for specified requirements.

One entire symposium was devoted to a discussion of problems of management of research and development which has now reached the proportions of "big business." The country will spend almost three billion dollars in research and development of discoveries during 1952. Of this amount, about $1,750,000,000, or more than half, will be spent by the government, whereas the remaining $1,250,000,000 will be spent by all other sources, including universities, foundations, and industry. With a good part of government-sponsored research cloaked in secrecy, the possibility for duplication of effort – with its consequent waste of critical man power, materials, and money – came in for comment by W. R. G. Baker, Vice-president and general manager of the Electronics Division of the General Electric Company. Dr. Baker, who was the recipient of the I.R.E. Medal of Honor this year, pointed out that many persons are alarmed at the extent to which government now participates in research and development. He called for a "wholehearted investigation to determine the over-all efficiency and the extent of duplication of governmental research and development" and urged that engineers from industry and educational institutions be selected to make such an investigation.

Certainly the radio industry would be hard hit if government-sponsored research in the electronics field were to be withdrawn. With the cost of electronic equipment alone in some new jet bombers costing more than the entire cost of two heavy bombers of World War II, and with the demand for technically trained personnel in the electronics field at fantastic heights, there are ample surface indications of prosperity. But one Technology Alumnus who is, himself, trying to employ technically trained personnel, took a peek under the frosting. It was his conclusion that engineers who wish to make a career in electronics be triply careful in any changes of affiliation they make under current conditions.

Constitution of Coal

THE formation of coal has generally been thought to take place in two distinct stages. In the first or biochemical phase, certain plant components are degraded and concentrated to produce the humic substances of peat or lignite. In the dynamochemical or metamorphic stage, the components of the low-grade coals are devolatilized to produce fuels having higher percentages of fixed carbon. Following the second phase of coalification, the original humic components have lost their identity and, therefore, it has been difficult to relate by chemical means the structure of the organic substances in the coal to that of the original plant components, such as lignin or cellulose. Since coal will undoubtedly gain increasing importance as a chemical raw material in the coming years, studies were undertaken in the Department of Geology in the fall of 1947 to obtain information on the basic chemical structure of most coals. The studies are sponsored by the Nova Scotia Research Foundation.

The relative contribution of cellulose and lignin to coal has long been a controversial subject. In order to consider the problem properly, a very thorough survey of the available chemical data was carried out from which it was possible to infer, on a theoretical basis, that lignin is probably the major source of humic substances and of coal, while, for the most part, cellulose is biochemically degraded and decomposed. In initial experimental studies, it was found that the infrared spectrum of lignin, isolated from wood, resembles very closely that obtained from humic acid isolated from peat. Further studies, carried out in Holland during 1951 by Irving A. Breger, '47, research associate on a Fulbright Fellowship, made use of the piles exposed when the city of Rotterdam was destroyed by bombing. These studies confirm the fact that cellulose is decomposed under burial conditions in which free oxygen is absent, and that while the lignin undergoes relative concentration, it is also converted into humic substances. Hence, there can be little doubt that lignin is the major contributor to most coals.

Further evidence in favor of the origin of coal from lignin has been obtained by vacuum differential thermal analysis, a technique developed during this research. While the structure of coal is so complex that relatively little information can be derived from chemical degradation studies, the method of thermal analysis provides data on changes which take place in coal while it is being heated under vacuum and at a constant rate up to about 1,000 degrees C. The information so obtained has shown clearly that the thermal records of decomposition of lignin and cellulose differ markedly, and that the thermograms of most coals, especially those of lower rank such as lignite, resemble closely that of lignin. By means of this technique, it has been possible to show how the structure of lignin appears in humic acid and then becomes less pronounced as coals of higher rank are examined. This seems to indicate that the basic structure of lignin is more highly polymerized and condensed with higher rank of the coal until anthracite is reached. At this point of polymerization and condensation, it is difficult to detect the fundamental structure of lignin in the coal. Preliminary experimental studies have shown that high pressure shear forces may be responsible in part for the conversion and devolatilization of humic substances into coals of higher rank.

Comparison of the temperatures, at which peaks on the thermographic record of constituents of coal derived from wood attain a maximum, gives a measure of the relative rank of the coals – that is, the higher the temperature at which the maximum of the peak occurs, the higher the rank. Studies have also been made of the thermographic characteristics of the constituents in coals, such as spores, resins, and fusain or mineral charcoal.

How to Pump an Oil Well

More than 100 years ago, the Englishman Charles Babbage set to work on a digital calculating machine that was to be capable of solving complicated mathematical problems numerically without need for any human intervention from the time the solution was started until the result was produced. Relying on strictly mechanical devices, and encountering considerable difficulty in obtaining the financial support required, Babbage failed in his attempt. His ideas lay dormant for many years.

Today the situation has changed. The availabilty of reliable electron tubes, supplemented by extensive facilities and techniques in the field of instrumentation, has removed the technical limitations which Babbage faced. The greatly increased need for rapid computation in the technological problems confronting us today has justified expenditures for general purpose digital computing machines such as the Whirlwind computer recently completed by the Digital Computer Laboratory at Technology. Work on the computer, which contains some specially designed memory tubes developed at M.I.T., was begun five years ago under the sponsorship of the Office of Naval Research. Recent sponsorship has been jointly shared with the Air Force, which is applying the Whirlwind computer to certain problems of air defense.

Whirlwind is also being employed in a variety of extensive computations on unclassified research projects as well. One of the problems, which has been under investigation at the Digital Computer Laboratory, concerns the production of oil from an underground reservoir. Work on this project is being supported by M.I.T., and the members of the Institute's staff who are working on the problem are collaborating with members of research staffs of various oil companies. The problem consists of calculating, on the basis of very incomplete information, enough about the expected behavior of an oil reservoir to permit the selection of a schedule of oil production to produce as much total oil as possible at an economically feasible rate. Ideally, oil should be pumped from a reservoir as slowly as possible in order to avoid leaving oil trapped underground, but the slower oil is pumped, the less profitable becomes the operation. Obtaining information on which to base an intelligent compromise obviously has very important implications to the effective utilization of the natural resources of the United States.

Even if the structure of underground oil reservoirs were completely known, which it certainly is not, the problem would be of considerable numerical difficulty. Unfortunately, the structure of various reservoirs varies widely and is not easily determined, even crudely, in any given case. A complete analysis is not available at M.I.T., nor elsewhere so far as is known, but significant progress is being made, even though the end result is not yet apparent.

An interesting problem being considered at the Digital Computer Laboratory deals with another important natural resource: the allocation of part of the radio-frequency spectrum to the new ultra-high frequency television channels. This problem has been programmed for the Whirlwind computer, but even the extremely high speed of the computer is not sufficient to make a complete answer readily available in a cut-and-try problem requiring some 10^{68} trials for the New England states alone.

An extensive academic program in numerical computation is being built up at M.I.T. Some parts of this are being handled by persons affiliated with the Digital Computer Laboratory. For example, a new graduate subject, a second-term continuation of a more general study of digital computers, is being offered in which the computer serves as a laboratory tool for potential users of such facilities. A special Summer Session program in Digital Computers and Their Applications will be offered next July by Charles W. Adams, instructor in Electrical Engineering, and Jay W. Forrester, 6–45, Director of the Digital Computer Laboratory. Extensive use will be made of the Whirlwind computer as a demonstration and practice device.

The extremely high speed of the Whirlwind computer makes possible the study of such systems as the control of air traffic into an airport. Such control applications lead to studies of the effects of the discrete sampling of continuous data on the operation of a control system and studies of the use of digital computers as data filters. A new graduate subject is planned by William K. Linvill, 6–45, Assistant Professor of Electrical Engineering, in which the problems of sampled-data systems will be analyzed for the benefit of students interested in this new field.

The recently organized Committee on Machine Methods of Computation serves as a clearing house for the computational problems of M.I.T. staff, graduate students, and others.

While engaged in research problems involving extensive computation, Whirlwind computer, a portion of which is shown below, enhances the educational program at M.I.T.

Chemistry of Plaster

As might be inferred from the name, finish, or white coat plaster is used for finishing walls. When properly applied, the smooth, white surface may be painted, papered, or left undecorated. Although generally a satisfactory construction material, finish plaster is not without certain defects whose elimination is a desirable objective.

Over the past 20 years, several investigators have undertaken studies of white coat plaster to improve its properties. Most of these investigations have been made primarily with the intent of explaining plaster failures, and with the aim of settling the highly controversial issue of whether or not the failures may be due to the resultant expansion which occurs when hydration converts magnesium oxide to magnesium hydroxide after white coat plaster is applied on the walls.

During the past two years, an investigation of white coat plaster has been under way in the Building Materials Research Laboratory at M.I.T. Under the direction of James A. Murray, Associate Professor of Materials, this investigation has been directed at learning the nature of the chemical changes occurring in plaster as time progresses.

White coat plasters, prepared from 16 commercial hydrated limes, have been aged under controlled conditions for more than two years: At various ages, these have been analyzed by differential thermal analysis. Significant differences have been found between the several white coats, particularly with regard to such factors as the rate of carbonation of the $Ca(OH)_2$ portion, the rate of hydration of the MgO portion, and the retention of free and/or adsorbed water.

Upon exposure of the white coat to normal atmospheric conditions, the rate of carbonation of the $Ca(OH)_2$ portion is of particular interest. Free $Ca(OH)_2$ is known to be a deleterious substance when in contact with paint films or wallpaper because of its saponifying and bleaching action. For this reason, a freshly plastered wall should not be painted or papered until the $Ca(OH)_2$ has substantially been converted by atmospheric CO_2 to calcium carbonate. This investigation has shown that the rate of carbonation is primarily a function of the commercial type or brand of lime used in preparing the plaster. Some white coats showed substantially complete carbonation in as short a period as seven days, whereas others did not attain this degree of carbonation in a year.

With respect to the hydration of the MgO portion of the plasters, it has been found that here too a variance is exhibited between different limes. Some of the limes used were apparently more active than others although, in general, it may be stated that very little, if any, hydration of the MgO occurred up to an age of one year.

Thermal analysis data have shown that some plasters hold water more tenaciously than others even though all the plasters studied were stored under the same conditions of temperature and humidity. This retention of water can be an important factor since a certain amount of moisture is necessary to bring about the reaction between $Ca(OH)_2$ and CO_2 and thus has a bearing on the rate of carbonation.

Diffusion of Gases

The energy of interaction between two molecules varies with the separation distance between them. At very close distances the molecules repel each other, but at larger distances they attract. For separation distances of the order of molecular dimensions, quantitative information concerning these interactions permits correlation and prediction of many properties of gases, liquids, and solids. Among these properties are viscosity, heat conduction, diffusion, thermal expansion, compressibility, lattice spacing, and heats of transition. Conversely, a study of these properties as a function of temperature helps provide desired information about molecular interactions.

In the Department of Chemistry, Isadore Amdur, Professor of Physical Chemistry, and his associates, have undertaken a series of diffusion studies to obtain such information for systems of like, as well as of unlike, molecules. Another purpose of these studies is to check the theoretical treatment of gaseous transport properties developed independently in 1917 by David Enskog and Sydney Chapman, the outstanding contributors in this field.

The availability of radioactive tracers has greatly facilitated these investigations by providing a relatively simple method for continuously following the rate of diffusion. In principle, the apparatus consists of a long brass tube with a center slide which can divide the tube into two gas-tight sections. With the slide closed, one section is filled with a gas, a small fraction of whose molecules contain radioactive atoms, the other section contains gas at the same pressure, but free of radioactive tracers. The slide is then opened and the diffusion is followed by measuring the saturation ionization current collected by internal coaxial electrodes in the two sections of the cell. The currents, of the order of 10^{-11} ampere, are measured with a specially designed, null type, direct-current amplifier which is capable of detecting currents as low as 10^{-15} ampere.

To date, investigations have been completed of the "self-diffusion" of CO_2 and of the mutual diffusion of CO_2 and N_2O between temperatures of –78 degrees C. and 90 degrees C., using $C^{14}O_2$ as the tracer. It had been assumed previously that the mutual diffusion coefficient for the isostere system,* CO_2-N_2O, would be the same as the self-diffusion coefficient for CO_2. The present results, however, show that the diffusion coefficient for CO_2-N_2O exceeds that for CO_2-CO_2 by about 2.5 per cent over the complete range. Expressions were obtained for the molecular interaction energies for the two systems which showed that, for work of high accuracy, it is not possible to assume that the energy of interaction between isostere molecules is the same as that between either pair of like molecules.

Current research on gaseous diffusion using radioactive tracers is concerned with measurements of the self-diffusion of CO, the mutual diffusion of the isostere system, CO-N_2, and the effect of composition on the mutual diffusion of the system A-Xe.

* Isosteres may be defined as molecules which have the same mass and electronic structure.

New Frontiers in Science

Through Co-operation of Diversified Groups, a System for Utilizing the Findings of Science Has Been Developed Which Brings Benefits to Man at an Accelerated Pace

By THOMAS K. SHERWOOD

In the mind of the ordinary person, the most important thing about science is that it has provided the basis for the great technological developments of "better things for better living." It is well to recall, however, that the influence of science on society has been considerably more profound than the material benefits for which we give it credit.

Two great wars in this century have resulted in the death of nearly as many people as there are in this country; a total perhaps twice as great as all the war deaths of the preceding 1900 years of the Christian Era. Yet the expectancy of life at birth has steadily increased with the years and done so at an increasing tempo. Even in the dark days of 1940–41 in Britain, the death rate actually declined below that of peacetimes. In the days of the great Roman Empire, the Romans lived an average of 22 years. When the author was born his life expectancy was 49, but the new-born child today can expect to live 68 years. More years have been added to man's lifetime in the last half century than during the preceding 1,000 years.

The impressive results of the medical sciences, and the supporting industrial technology are well illustrated by these statistics on life expectancy. But equally impressive are the increase in living standards and the reduction in the hard labor required for living. Slavery in the British Empire was not abolished until 1834 and, in the United States, its abolition occurred less than a century ago. Since 1850 the work week has been shortened from 70 hours to 43 hours, and the first generation of laborers in history has known leisure time. I estimate that a man today works about 80,000 hours in the course of his lifetime, sleeps 200,000 hours, and has 320,000 hours left for himself. His working hours represent less than 15 per cent of the total. He has four hours free, awake, for every hour he works. In 1900 the ratio was only about 1.6 instead of four. Nearly 2,000 years elapsed, between Archimedes and Newton, but it is only in the past 50 years that man has doubled his hours of leisure.

Leisure time is not an end in itself, but it gives man freedom and power in the most fundamental sense. One bushel of grain, representing a measure of the necessities of life, cost the English laborer the equivalent of six days' hard work in the reign of Elizabeth; today a bushel of grain is equivalent to less than three hours of labor. The gain is available for what man pleases — for education, recreation, loafing, or for the all-out effort of war.

Leonardo da Vinci understood the principles of flight 400 years before the Wright brothers first flew, which they did in the year I was born. Today air travel is routine, and on this continent air travel (passenger-miles per year) exceeds the corresponding figures for Pullman travel. Jet propulsion is but 10 years old, yet jet engines are now being used for air-passenger service. Air travel with nuclear power

Boeing Airplane Company

Jet propulsion is but 10 years old, yet jet engines are now being used for air passenger service.

plants, if not "just around the corner," appears to be entirely feasible. Our time scale is indeed collapsing, and it is no wonder that the public confidently expects a scientist to make a trip to the moon almost any day.

The automobile, not much older than the airplane, has proved to be an essential labor-saving device. Its brother, the tractor, has made it possible for a smaller farm-labor force to grow food for more people. The new textile fibers have freed us from dependence on the silkworm, and it now seems probable that wool will shortly be replaced by something better. Motion pictures, radio sets, and record players have brought entertainment and good music to millions, and the writer notes that, in M.I.T. dormitories, radio receivers are tuned as often to classical as to popular music. Central heating, electricity, washing machines, refrigerators, and dishwashers have largely eliminated drudgery from the home. In passing, the writer admits to a slight doubt regarding home labor-saving devices, since he spends some of his 320,000 hours of leisure time repairing the toaster, vacuum cleaner, power lawn mower, or other gadget.

The developments in medical science in very recent years have been particularly spectacular, and it is not possible to list even the more important ones. Although the statement cannot be documented, it seems probable that two antibiotics – penicillin and streptomycin – have saved more lives in the last six years than were lost during World War II by Britain and the United States combined. It now seems likely that synthetic cortisone will be commercially available within two years at most, and the rapidly developing chemistry of proteins, steroids, and hormones bids fair to produce new wonder drugs.

Ford Motor Company

It now seems likely that synthetic cortisone will be commercially available within two years at most, and rapidly developing chemistry of proteins, steroids, and hormones bids fair to produce new wonder drugs.

But why has the rate of scientific progress increased so rapidly during the last generation? It is true that we have many more scientists, but I see no evidence that they are better scientists than Newton, Boyle, Carnot, Lavoisier, Faraday, Thomson, or other great names of the past. I believe that the answer lies in the relatively new invention and development of a system for utilizing the results of science. This is the system of teamwork among scientist, engineer, and manufacturer.

Let us review how this system operates in a particular case – the spectacular development of inexpensive penicillin. Wolff in the Eighteenth Century, and Koch and Pasteur in the Nineteenth Century, had discovered the cell structure of tissues and laid the foundations of modern bacteriology, but it was not until 1929 that Sir Alexander Fleming noted the bactericidal action of the mold *Penicillium notatum*. Sir Howard W. Flory and his co-workers at Oxford obtained pure penicillin in 1940 and its nontoxic and antibiotic characteristics were quickly established. At this point, the work of the scientists was essentially done, and engineers in industry took over.

Incidentally, one of the first lives saved by penicillin was Churchill's, and thereby hangs a tale worth relating. About 1890, an English school boy was vacationing in Scotland. One hot day he stopped at a small lake and went for a swim. But the water was very cold, and the boy developed bad cramps in his legs. He was beyond his depth, and was about to drown, when a young Scotch farm boy swam out and pulled him into safety.

Hearing of the incident, the English boy's wealthy parents traveled to Scotland to look up the lad who had saved their son. They found the Scotch boy to be poor but of great intellectual promise, and they rewarded him by financing him through the university.

The scene of the second part of this story is Cairo, about 1942, where Prime Minister Churchill lay terribly ill with pneumonia. A wireless message brought Dr. Fleming by airplane from London, with just about the world's supply of penicillin in his pocket. The penicillin worked its wonders, and so, for the second time in 50 years, Dr. Fleming had saved Mr. Churchill's life.

The rest of the penicillin story is well known. Teams of engineers and scientists developed methods of growing the precious mold in thousands of large flasks; submerged fermentation eliminated the flasks and led to large-scale production in tanks holding many thousands of gallons each. Chemical engineers developed plant processes for the recovery of the penicillin from the exceedingly dilute fermentation liquors. Biologists and chemists developed analytical techniques. Packaging methods were worked out for handling the product under sterile conditions. The price of penicillin dropped from $20 to $0.04 per 100,000 units, and the death rate from pneumonia has been cut in half. A new multimillion-dollar business is now thriving where nothing existed before there was teamwork of scientist, engineer, manufacturer.

This is a story of teamwork. Scientist, clinician, biologist, technician, chemical engineer, chemist, plant foreman, laborer, and company executive –

(*Continued on page 312*)

Harold M. Lambert

Audio Engineering Comes into the Home

Engineering Achievements in Sound Recording and Reproducing Systems Account for the Current Popular Interest in Music for the Home

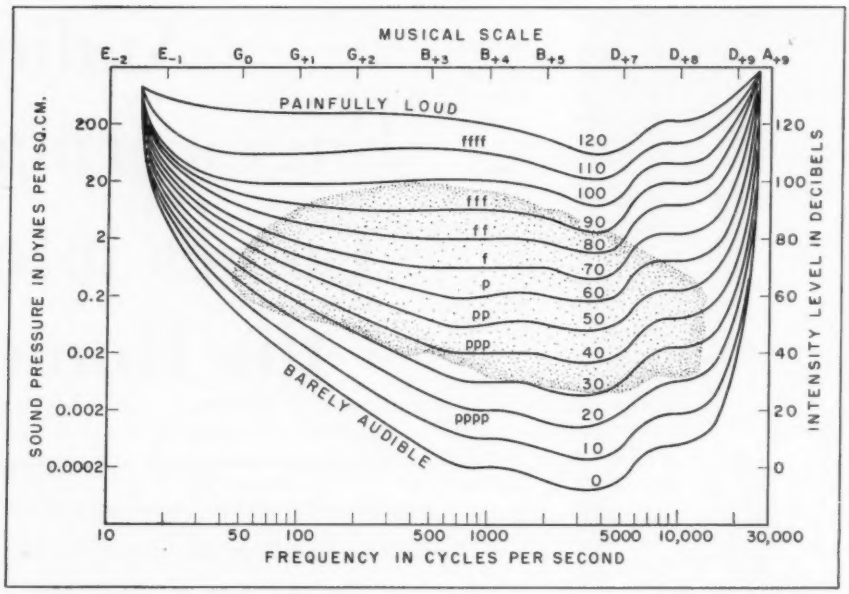
By C. J. LeBEL

It has been conventional to cite the proverbial "man bites dog" as an example of the totally unexpected, but occasionally an industry bites the experts. If experts can find neither technical nor economic justification for the new industry – whereupon it doubles in size every year – the result can be very interesting.

The audio industry is a good example of such unexpected rapid growth. It is a good example, too, of the rapid flowering of techniques which takes place when the opportune time has arrived. As the oldest branch of electrical engineering (which began with the commercial use of the telephone) audio engineering long preceded the commercial power branch. Philosophically, the comparative antiquity of this branch of engineering seems logical, for the need for sound, speech, and music certainly preceded man's requirements for electrical power. Moreover, from many points of view, the scientific and engineering basis of audio engineering is certainly broader and more general than that underlying other phases of electrical engineering. An example of this statement immediately comes to mind when we consider the range of frequencies involved in these two fields. A band of frequencies of from 20 to 20,000 cycles per second, about 11 octaves (representing a ratio of about 1,000 to one) is required for good reproduction of sound, whereas power engineering deals almost exclusively with 60 cycles per second or some other single frequency. Even the frequency spectrum encountered in radio engineering seldom deals with more than a fraction of an octave in any given instance.

The audio industry serves a large field having many ramifications of a highly specialized nature. For example, it serves and is concerned with architectural acoustics, public-address systems, interoffice-communication systems, radio and sound motion-picture equipment, sound recording by tape and disc, and various methods of reproducing "canned" music, including the juke box. Since the field is so large, this article will concentrate on merely a small facet of the whole and will emphasize recent developments which make possible high-quality reproduction of sound in the home.

Our respect for the field of high-quality sound reproduction for home use rises when we realize that total sales in 1950 were estimated at $250,000,000. This sum represents a very substantial fraction of the 1.3 billion dollars taken in by the entire home radio-television-phonograph field. Radio jobbers who have featured equipment for high-quality reproduction of sound have increased their business in startling fashion by thus catering to the connoisseur.



Based on the research work of Fletcher and Munson of the Bell Telephone Laboratories, this diagram indicates the relationship between frequency (or pitch) and sound pressure (or intensity) to which the normal human ear responds. No hearing occurs below the zero contour marked "barely audible," whereas sound becomes painful for intensities just above the words "painfully loud." The dotted area represents the range of frequencies and sound levels encountered in orchestral music. The musician's intensity scale is a subjective and personal one which cannot be accurately related to the curves shown, although the f *and* p *designations have been included to give a general impression of a possible correlation.*

M.I.T. Illustration Service

New Developments in Sound Reproduction

For many years the tone quality of most mass-produced home radio sets and phonographs remained at a low level through limitations imposed by the high cost of cabinets, and by the lack of adequate audio engineering. A large part of the cost of such equipment went into cabinet work to satisfy eye appeal and few manufacturers have been seriously interested in making an all-out effort to obtain the best tone quality possible with the money available. The engineering departments of radio manufacturers have traditionally been headed by radio engineers, and designs have accordingly reflected radio thinking. Radio sets have been designed primarily for picking up weak signals, and only secondarily for making the signals sound as good as possible. A number of studies have been advanced to demonstrate that the public could not recognize and would not pay for good tone quality in home radio equipment. Nearly all these proofs were based on the common misunderstanding of radiomen that wide tonal range and high quality were synonymous.

Actually, the public was often repelled by the high distortion (and noise) that usually accompanied the sound when reproduced on equipment which the average radio engineer regarded as being of "high fidelity." The public also objected to the surface noise of the average disc record. Despite this, one large manufacturer was able to achieve outstanding commercial success in the 1930's by consistently producing radio receivers which were less fatiguing to listen to and of better tone than those of his competitors.

Today the purchaser of high-quality components (such as improved loud-speakers and cabinets, amplifiers, records, and record changers) finds that he can achieve startlingly better reproduction of sound in his home than he could have with a standard mass-produced unit at several times the cost. Furthermore, he can secure the features which he wants, which, in many cases, are not available at all in standard radio-phonograph units. Finally, he can fit the components into the most convenient locations and is not required to move everything around to fit a cabinet of arbitrary size.

Many reasons may be advanced for the rapid rise in the use of truly high-quality sound reproduction in the home. Undoubtedly the availability of well-designed equipment and components, which has made possible the bringing into the home of operas and symphonies with reproduction comparing very favorably with the original rendition, has been an important factor. So too have been the altogether too few instances of good music programs which can sometimes be heard on the usual broadcast channels or the higher channels used in frequency modulation. Undoubtedly a controversial issue is raised by suggesting that public apathy toward mediocre radio programs and sound motion pictures has had its influence in promoting the sale of equipment which brings into the home that music which the listener wants to hear, when he wants to hear it, and without the accompaniment of obnoxious advertising chatter. Nevertheless, the success of those radio stations which have attempted to generate high-quality program material (such as WQXR in New York, or WGBH in Boston, for example) indicates that not everyone is forever going to be satisfied with "soap opry" or Howdy Doody.

Some Long Words Simplified

A discussion of the methods by which sound is reproduced entails the use of terminology which reflects the specialties of the engineer, the musician, and even the psychologist. If we are to avoid the pitfalls of appealing to one or two of these groups rather than to all three (as well as the reader), it will be beneficial to come to a common understanding of the terms employed. Perhaps this can best be done by giving a very brief – and not too technical – re-

view of the elements of hearing and sound reproduction.

It is common experience that persons with normal hearing can distinguish audible tones on the basis of their frequency or pitch, as well as on the basis of their intensity or volume. Willfully ignoring some of the more subtle points which interest the serious student in this field, we may say that pitch is the musician's term, whereas frequency is the engineer's term for the number of vibrations per unit time. Hearing studies have shown that the "normal" ear can hear airborne vibrations of from approximately 20 to about 20,000 cycles per second, corresponding approximately to the 11 octave range from E_{-1} to E_9 on the musician's scale. The range of tones which may be heard by persons of normal hearing depends not only upon their age and physical well-being, but also upon the intensity or volume of the sound. The ear is most sensitive in the range of middle tones, from about 500 to 5,000 cycles per second or, roughly, from B_3 to D_7. Within this portion of the audible spectrum, the ear can sense sounds whose volume or power intensity extends over a range of 10 trillion to one. In the musician's language, this 10^{12} ratio covers the volume range from exceedingly soft to exceptionally loud sounds. The ear is not uniformly sensitive throughout all of the tonal range it hears, however. At the extreme frequencies, the minimum sound intensities which can be heard are also those which are simultaneously so intense as to produce pain; beyond such points, the term "hearing" has no meaning, of course. The nonuniform sensitivity of the human ear requires that equipment intended for high fidelity reproduction of sound be designed to take account of such physiological factors.

Sounds of music or communication are not pure tones, but are a highly complex synthesis of components of many frequencies; they almost invariably have very complicated wave forms. The presence or absence of harmonics is one of the factors which enables us to distinguish sounds of various voices (or those produced by different instruments) when both sound the same fundamental pitch.

From the engineer's point of view, sound – vibrations of air molecules – may be produced by the vibration of a diaphragm (in a loud-speaker or telephone headset) which in turn is actuated by electrical power from an amplifier at the output end of the electronic system. The electrical signal fed into the amplifier may be the electrical variations from a radio receiver or a microphone. Where sound is to be "canned" for reproduction at some later date, the original sounds may be impressed as mechanical undulations in the spiral grooves of a disc record, or as variations in the magnetic condition of a wire or tape. In any case, a whole series of elements in a chain are required to convert sound into its electrical counterpart and then back, after suitable amplification, into sound energy.

Even this brief and very elementary discussion is sufficient to show that any system for the reproduction of sound must be designed to meet exceedingly stringent requirements if the end product is to be a faithful replica of the original sound. For example, such a system must operate over a very wide range of frequencies, and also over a very considerable range of sound intensity, and it must do so without appreciable distortion or change of wave shape, and without introducing noise. In practice, no system is able to fulfill these requirements fully over the extreme ranges which are desirable. The best we can hope to do, in any practical case, is to design and build sound-reproducing systems whose performance is sufficiently good that the difference between ideal and actual performance is accepted as being small even to the trained ear. Such achievements are now possible and at costs which are very modest, considering the complexities of the problem.

New Development in Discs

Notwithstanding much interest in radio and television, and the use of magnetic tape for reproduction of sound in the home, a number of factors conspire to favor the disc. Time has proven that the manufacturers who elected to pioneer the new disc developments were wise in their engineering foresight.

The most obvious advantage in the use of dics is the ease of selecting the desired material. With a disc the records may be loaded on the turntable in a second, and the needle placed in the desired groove in another second. With tape recordings the ribbon must be threaded through the reproducing head and run until the desired point has been reached; often this operation becomes a matter of two or three minutes.

As compared to music reproduction by discs, entertainment by radio suffers from two serious handicaps. The more obvious of these is the difficulty of program selection. When the available radio programs are uninteresting to the serious music lover, he has to find his preferred material on a disc. The more subtle handicap of radio programs is one of listener fatigue, induced by a minor economic consideration. To date all the networks (except for one minor FM group) lease long-line telephone circuits which will transmit frequencies up to only 5,000 cycles per second – far short of the normal hearing limit or the range of 12,000 to 15,000 cycles per second which can be recorded on discs. For a number of reasons such a hedged-in range, reproduced over a still poorer home radio receiver, is a strong inducement to listener fatigue, and consequently, after a while the victim yawns and turns off his set. On the average, telephone circuits of improved frequency range would increase the cost per radio station by an amount less than the present salary of one good technician. Lagging set sales and reduced hours of use in any locality where television ceases to be a novelty supports the thesis that television has little to offer to those seriously interested in good music. Bedeviled by the problem of unobtrusive pickup of sound, television has too often enforced very poor microphone locations; the microphones are inconspicuous but too often wretched sound results. If the program is shown on both radio and television, the microphone positions are still dictated by the need to elude the ubiquitous lenses. So, in a way, television has injured the sound quality of broadcast programs.

The radio station which caters especially to the serious listener can bring him fine reproduction via records and radio transcriptions. In this way much good material can be made available economically, but radio programs provide no answer to the listener's desire for given material at a specified moment.

The new developments in discs make possible increased convenience and lower cost per minute of recorded time. At the same time, they make a greater part of the disc cost available for improved material and better workmanship. As a result of these factors, sound by discs is presently enjoying its biggest boom.

Improvements in Sound Reproduction

In the late 1930's, components for building better home equipment for sound reproduction became generally available to the technically inclined, and one large manufacturer of records began development of discs which could be made relatively free from surface noise, without costing more to make than the old style disc. Development was retarded during the fighting, but was resumed after World War II.

The best disc in the world is of no avail without suitable means for properly converting the undulations of its spiral grooves into electrical energy. As better discs were evolved, the need for accessory phonograph components became apparent and development work was begun. At first, attention was directed to the improvements in the mechanisms – called reproducer heads – for converting mechnical motion of the phonograph needle into electrical energy. Improvements in this field called for corresponding betterment of the supporting arm and turntable. In time wholly new and greatly improved reproducer heads were developed which reduced wear of the record. Engineering analysis was applied to the design of the supporting arm to obtain greater freedom from undesired resonance effects and to produce less distortion as the arm traveled from outer to inner grooves, and turntables were designed and built for greater mechanical precision to attain constant speed during operation

Improved reproduction, which the new discs made possible, forced an improvement in amplifiers, loud-speakers, and other elements in the sound system. For the first time in many years, new amplifier circuit principles were discussed. Various types of amplifiers for home use, with unusually uniform response over the entire audible tonal range, were developed. These would develop their rated "undistorted" power output over an unusually wide frequency range, so that extremely low and high frequencies were amplified as clearly (as well as loudly) as tones in the middle range. By the use of better output transformers between the amplifier and the loud-speaker as well as by special circuits, distortion was reduced to match the lower distortion of the new reproducers and discs.

As the final link in the chain, better loud-speakers were developed. Improvements in speakers made possible wider tonal range with better reproduction of the transients which form such an important part of music. Some attention was also given to more uniform distribution of sound, so that the sounds of higher frequencies would not be concentrated in a narrow beam as formerly was the case.

Microgroove Records

It is possible to increase the playing time on a disc of a given size by placing the grooves close together, or by allowing the disc to turn more slowly. Both expedients are used in the modern disc. If we were to reduce the disc speed only, we would find that the undulations in the groove convolutions had become so fine that the tip of an old style phonograph reproducing stylus could not follow them with the desired detail, and harsh tracing distortion would result. It was this that spelled the doom of the first widely sold long-playing home records in the early 1930's.

In the modern disc a finer groove (called microgroove) is used. The reproducing stylus has a tip of smaller radius in order that it may follow the finer details with negligible tracing distortion. Improvements in disc materials also made possible drastic reduction of surface noise so that it became feasible to reproduce frequencies as high as 12,000 or 15,000 cycles per second, which is very close to the upper frequency limit of hearing for the normal human ear.

By obtaining more playing time on a record of given size, the cost of materials for discs, per minute of playing time, was reduced to the point where the quietest and costliest pressing stocks became commercially feasible. This has led to extensive use of unfilled (pure) and lightly filled vinyl stocks in place of the heavily filled shellac which was so common 10 years ago.

The idea of microgroove is old, being based on the research work of Frederick V. Hunt of Harvard University and his collaborators in the late 1930's. The application of microgroove principles to commercial home phonograph records seems to stem from the work of Rene Snepvangers at RCA Victor in the early 1940's, but extensive use had to await the development of commercial reproducers so light that they could track a groove with only six grams of force on the stylus.

Microgroove developments have followed two paths: in one case a seven-inch disc now provides five minutes of playing time per side, which had long been standard; in the other case, the long-playing 10- and 12-inch discs increase the nominal playing times to 15 to 22 minutes per side, although 28 minutes is possible. The seven-inch disc has proven well suited to the recording of single selections of popular music, and it is claimed that this field is 80 per cent of the potential market. The long-playing discs of larger diameter have uniquely filled a need in the fields of classical music and drama. In the seven-inch size a battle has raged between proponents of 33⅓ and 45 revolutions per minute. and the higher speed seems to have won. In the field of long-playing records a speed of 33⅓ revolutions per minute has not been commercially challenged, although a recent study by an engineer of the British firm, Electrical Musical Industries, seems to point toward the advisability of 45 revolutions per minute.

Modern Disc Recording

So far as concerns the ultimate consumer playing records in his home, the best modern discs are able to reproduce all sounds equally well up to about 12,000 or 15,000 cycles per second. Such essentially uniform response throughout the audible spectrum is not easily obtained, however, and the fact that it is, is a tribute to those who have designed and made possible modern recording techniques. A number of separate and independent operations must be gone through before it is possible to stamp out the disc for the home user. In each step the highest degree of engineering skill is required if the end product is to be capable of reproducing all audible sound without appreciable distortions.

The first step in the production of modern records is to make the initial recording on a magnetic tape. This recording is edited, and re-recorded onto a blank disc of aluminum, coated with special lacquer, for wax• has been obsolete as a "master" material for more than a decade. To secure the lowest noise level and the widest frequency range, a heated cutting stylus is generally used in making the master disc. The resulting lacquer master is plated to produce a metal master negative, and by further electroplating, mothers (positives) and stampers (negatives) are made. Production records are pressed from the stampers.

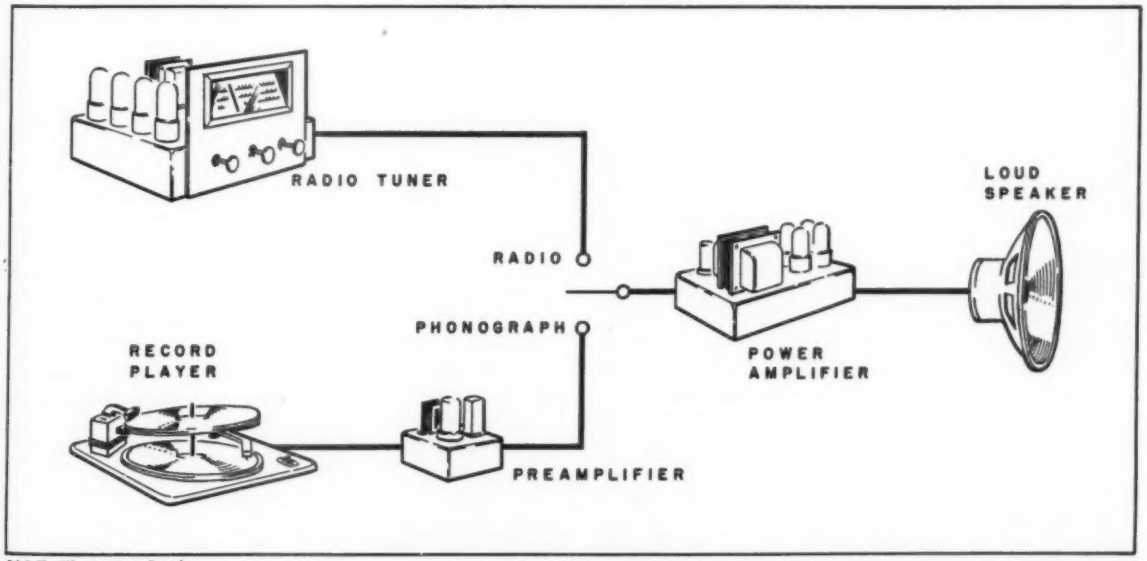
Commercial records have always been too variable in quality; but now that the economic factor has been minimized, there is less excuse than ever for variability. One means of reducing variability has been the use of tape recorders, whose mechanics of operation are so simple that almost anyone can produce an *approximate* facsimile of the input. In the smaller organizations, almost anyone does record — one firm even used a record critic! There has been a tendency for semi-skilled operators, lacking a good technical background, to record at too high a level. The machine noise is better subdued thereby; but peaks are clipped, deleting much of the accent and emphasis which make a musical selection of interest. Crescendos somehow do not quite materialize, and the result is tasteless.

Many long-playing records have been produced by re-recording from older 78 revolutions-per-minute records of the 1930's. To reduce the noise level to a tolerable point, the response at the higher frequencies is often virtually extinguished. Too many German wartime broadcast tapes, recorded on the early Magnetophones, have been used, with doubtful frequency range and occasionally high distortion. Such practices cannot result in records which meet modern standards. Since even a poor recording can be sold if the artist is sufficiently well known, there has been a tendency to rush production and to relax some of the high standards of two years ago.

Finally, we still have a mild degree of anarchy as regards recording characteristics. In order to minimize surface noise it has been necessary to subdue the lower tones and accentuate the higher pitched tones during recording. The degree to which intentional emphasis is thereby given to the higher frequencies is called the recording characteristic. In order that the final result may be as intended, an exactly inverse compensation (called the reproducing characteristic) should be used during reproduction of the disc. It has proven impossible to define the recording characteristic exactly, for it is affected

(Continued on page 320)

• Incidentally, "wax" is not a wax at all, but is a metallic soap.



M.I.T. Illustration Service

The essential elements of a sound-reproducing system for home use are illustrated in this block diagram, Sound reproducers using magnetic tape or wire may be used in place of the more popular disc recorder shown here. When basic audio components, such as those indicated above, are assembled into suitable cabinet furniture, the music enthusiast can reproduce at will "live" or "canned" music, no matter whether his taste runs to Bach, Beethoven, and Brahms, or to boogiewoogie.

M.I.T. Photo

Most of the Institute's internal telephone service is concentrated within the area bounded by the white band shown in this aerial view of that portion of Cambridge bordering the Charles River basin.

Telephone Service for the Institute

Adequate Communication for 10,000 Persons along One and One-quarter Miles of Charles River Front Poses Some Unusual Problems in Telephone Service

By CARLTON E. TUCKER

THE question is often asked why an educational institution needs so much telephone service. The air view of the Institute property gives an indication of the area served by the Institute's telephones. The population served includes about 2,300 on the teaching and research staff, 2,500 other employees, and 4,900 students. In round numbers, this population totals 10,000, or equal to that of a moderate-size town.

The area served by the telephone exchange of a medium-size town might be 20 to 30 square miles and a base rate area* might encompass 10 to 15 square miles. With its 1,804 line terminals, the Technology Exchange has at least as many line terminals as the exchanges serving more than one half the towns in the state. The distance from the Supersonic Wind Tunnel, which is near the Boston University Bridge, to the Sloan Building (formerly Lever House) is approximately a mile and a quarter. The Institute's exchange area extends from Memorial Drive on the south, to Vassar Street, or to the Boston and Albany Railroad tracks on the north, and in the cases of the Hood and Whittemore Buildings, even includes some area across the tracks. This distance averages one fifth of a mile, making the area served by the Technology exchange about one quarter of a square mile. Counting only the area covered by the buildings having direct cable connection to Building 10, in which the switchboard is located, the Institute's base rate area covers one twenty-fifth of a square mile. All buildings in the Technology exchange are connected by underground cable to the main frame located in Building 10.

In order to serve a population of 10,000 persons concentrated in an area of one quarter of a square mile, the Institute has been utilizing a total of six private-branch exchanges, including the one now enlarged from 1,400 to 1,800 lines. The recent expansion in the Institute's telephone service† makes possible the consolidation of these small switchboards into one large switchboard, making it economically feasible to provide 24-hour coverage for all from one central location.

Technology has long enjoyed the advantage of having most of its activities under one roof. This has resulted in close association between Departments and in the building of a unified Institute. The continuing expansion of our activities into many sepa-

*The base rate area is that area for which the minimum service charge applies.

†"M.I.T. Expands Telephone Service," The Technology Review, 54:251 (March, 1952).

rate buildings, over a wide area, tends to break down some of these contacts. A unified telephone system, serving the entire Institute, helps preserve these former close relationships which are so important to successful teamwork between Schools and Departments at the Institute.

The Technology Telephone Office contains a large operating room, 16 by 21 feet, for the new four-position manual section; one switch room, 23 by 34 feet; and a second switch room, 10 by 14 feet. An operators' rest room will be provided in the space now occupied by the former manual board. The entire space is air conditioned by a five-ton unit.

To provide outgoing service in the local metropolitan area, a total of 47 lines, terminating in the University central office, are provided. Those lines are associated with toll-diversion equipment, so that only local calls can be made, and attempted toll calls are referred to one of the M.I.T. operators. Incoming service, as well as outgoing toll service, is provided over 40 manual lines from the Kirkland central office.

One of the features of the M.I.T. system which makes for distinctly improved telephone service is the block numbering arrangement used in conjunction with automatic hunting over consecutive numbers. The major courses of instruction at the Institute are numbered, as are also their subjects of instruction. The telephone numbers are similarly classified. For example, Electrical Engineering is Course VI and therefore has extension numbers starting with the digit "6." The numbers are arranged in groups of 10, with the number ending in "1" available to a secretary. If, as often happens, "Don't Answers" result from a professor's being in class, it is generally possible to hang up, redial the call, changing the last digit to "1," and locate a secretary, who is nearby the office of the professor in question. She can put a message on his desk asking him to return the call. The departmental arrangement of numbers on the manual board makes it much easier for the operators to locate individuals without referring to information directories.

The manual part of the system has a number of features not regularly provided in private-branch exchange switchboards which should make for improved service. These are:

Desk-height operating key shelf.

Small plugs and jacks making all line terminals within easy reach of an operator.

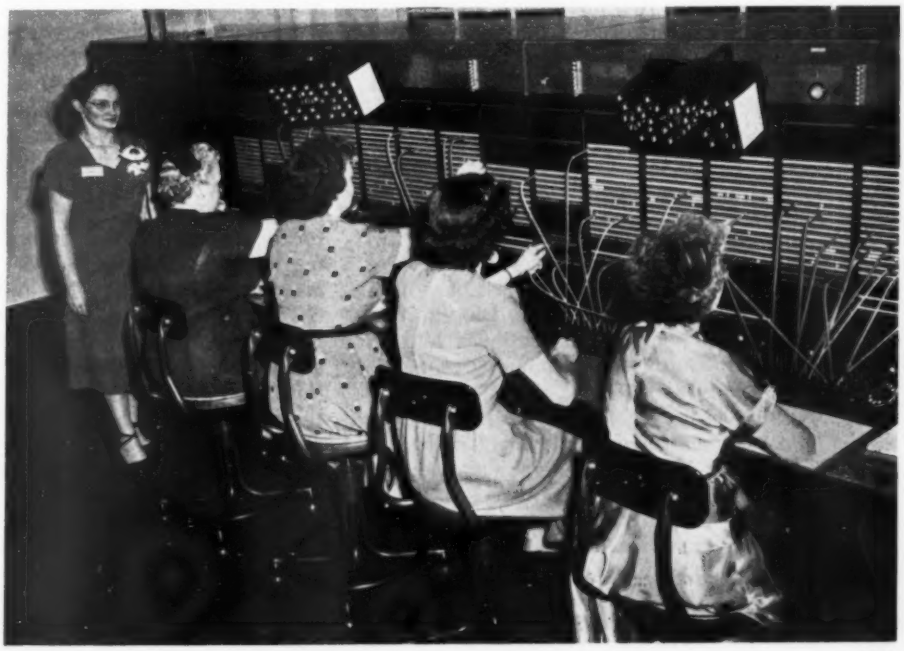
Automatic ringing when operator completes a connection.

Idle trunk-line lamp indicators saving the operator from testing when making an outgoing toll call.

Automatic flashing recall whereby telephone users can attract the operator's attention by depressing the handset cradle only once.

The handling of incoming calls for students in the four residence houses involves the use of a private internal system. Two of these houses use manual telephone switchboards with telephones in each student's room. The other two housing units are served by a 300-line dial system. This provides telephones in each room of one dormitory and in the corridors of a second. Students are called from the outside by dialing the Institute's telephone number, KI 7-6900. This call is received by, or referred to, the operator covering the information position. She has access to a complete Flexoline file of dormitory residents. After looking up the student's residence location, she calls the manual operator or the desk clerk in the house in which he resides. The dormitory telephone operator, or desk clerk, locates the student over the internal telephone system and tells him that he has an outside call. To provide for extending these incoming calls to the dormitories, some 88 extensions from the main switchboard are provided in the corridors of the four

(Concluded on page 318)



The Institute's new five position telephone switchboard was first put into operation on January 26. Efficient telephone service is provided by (left to right) Miss Agnes N. Morrice, Miss Agnes McDonough, Mrs. Margaret Donahue, Mrs. Barbara Whitney, and Mrs. Irene Riley.

M.I.T. Photo

Economics at M.I.T.

The Economics Staff, with Diverse Backgrounds and Views, Aims to Impart a Technique of Logic for Solving Economic Problems in a Complex Society

By RALPH E. FREEMAN

One of the most difficult problems confronting the professional teacher of economics is the competition he meets from other and more effective teaching agencies. The writer refers to the educational impact of the home, the press, and the radio, as well as the propaganda coming from special-interest groups of one kind or another. These agencies have a competitive advantage. The teacher may be in contact with his class for only two or three hours a week for a part of a year, while his nonacademic competitors have been working on these students since their early childhood.

This disadvantage may seem to raise the question as to whether the economist can really teach the subject at all. Doubts on this score are further increased by the unsettled condition of the world during the last decade—a state of affairs that has created many uncertainties for the individual. A student worried about his future can hardly be blamed for indifference toward a subject which often seems dull and remote from his immediate interests. Another disadvantage is the youth and inexperience of the average college student. Favorable experience with the veterans who came to the Institute after World War II indicates that maturity is a great advantage in the study of economics. All these difficulties in the way of the teacher tend to make him humble when appraising the impression he leaves on the minds of the younger generation.

These obstacles, however, are also a challenge to the economist to improve his teaching techniques. The Economics staff at the Institute has been continually experimenting with new materials and methods and, though it is not fully satisfied with the results, progress has been achieved. We have tried to keep up with the increasing mass of quantitative data becoming available and to keep abreast of improvements in analytical techniques and of shifts in emphasis resulting from changing economic conditions.

An interesting example of such a shift is to be found in the treatment of unemployment and price levels. Prior to the 1930's, these problems were of secondary interest to most economists. A great deal of what they wrote and taught was based on the assumption of full employment and relatively stable prices. The attention of economists was directed mainly to the way in which productive agencies were allocated among various industries and enterprises. The leading problem was to discover that distribution of human and material resources which would best promote the material well being of the people.

In recent years the economist's inquiry has focused on economic fluctuations. Unemployment of resources has thus become a major problem for investigation along with a study of changes in the level of prices. Because ups and downs in employment and periods of inflation and deflation are associated with changes in income available to purchase goods and services, the spotlight has been turned on income analysis. The study of national income has been stimulated by the publication of improved statistics emanating chiefly from the Federal Government and by the development of new and better techniques of analysis.

These statements are not meant to imply that the traditional subjects have been abandoned. The economist is still trying to explain what the economic system is and how it operates. He is still concerned with the role of prices and profits in organizing economic activity and with the functions of money and markets in assigning labor and capital to their more productive uses. What has happened is a reorientation of these traditional inquiries around the problems of income, employment, and price levels. This new approach seems to have brought the study of economics nearer to the daily lives of people and closer to the problems with which businessmen are most vitally concerned.

The fact that the beginner in economics is normally young and inexperienced makes it necessary for the teacher to spend a good deal of time describing the facts of economic life. National income, for example, only becomes meaningful as it is broken down into components and expressed in quantitative terms. It is usually desirable, therefore, to start with a discussion of the income of individuals, corporations, and governments. How is the total income of the nation divided among families and groups? How are corporations organized? How do they compute their earnings? What is the role of government and what changes are taking place in the relation of the government to the individual and to business? These are among the questions with which the student of economics is confronted in the early stages of his study. In addition, in most of the subjects offered, time is devoted to describing various institutions

such as banks, labor unions, and farmers' organizations which help determine the nature and direction of economic activity.

The main objective of economic education, however, is not to fill the minds of students with facts and statistics, but to impart to them a technique of thinking by means of which they can analyze and solve economic problems for themselves. General principles must be developed that are applicable to a broad range of situations. Among these principles are those that can be applied in understanding changes in the price of goods, changes in wages, interest, and profits, in the general price level and in the national income.

The economist is concerned, for example, not so much with what the price of wheat is or has been, as he is with the forces that interact to determine the price of wheat or any other commodity. Though he may study past changes in national income, he is primarily interested in the reason why the national income shifts from one level to another. In other words, he tries to develop an integrated theoretical framework which can be used in the analysis of economic problems.

At M.I.T., the economist is regarded as a teacher, not a preacher. His function is not to radiate his own political views nor to propagandize for his own particular social philosophy. His job is to encourage students to form their own opinions. He is not too concerned with what these opinions are. His main job is to ensure that the opinions, whatever they may be, are reached through a logical process of thought, rather than as a result of prejudice or hearsay.

The Economics staff of about 30 full-time members has been recruited with this objective in view. When a new man is taken on, we ask two main questions. Is he equipped by training, experience, and intelligence to carry on creative, scholarly work in his chosen field? Is his personality such as to hold out the promise that he will be a competent teacher and a congenial and co-operative colleague? As the result of this method of selection, the group we now have includes no freaks or extremists. Though there is a broad diversity of view on many of the controversial issues of our times, all of the members of the Department share a desire to preserve and improve the free institutions of America. These men rank high in the profession and compare very favorably with economists in other leading institutions.

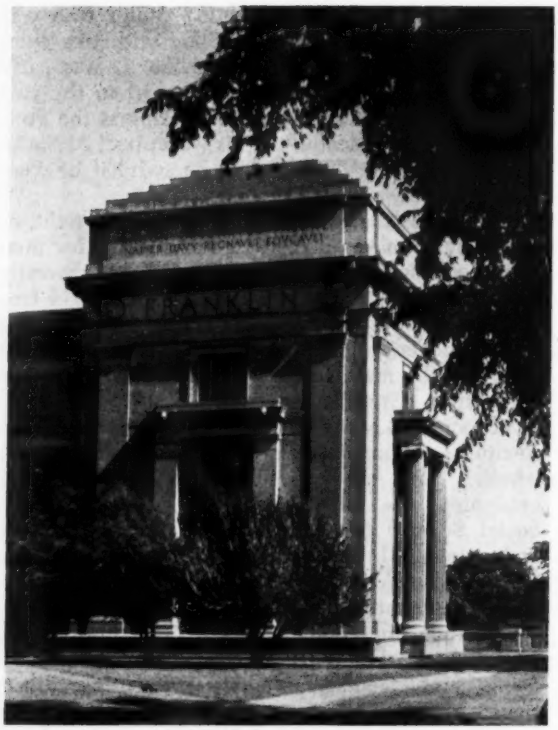
Some people may find it hard to accept the idea that divergence of opinion should be regarded as a healthy condition. Why, it may be asked, should I tolerate a colleague who disagrees with me on government controls, the merits of labor unions, taxation, monetary policy and other questions? My answer would be that differences of opinion give rise to a lively interchange of ideas which is an important element in the educational process. Progress in economics, or in any other scientific discipline, would be stifled if an effort were made to enforce conformance to a single pattern of thought.

No matter how firmly we may believe that a given policy is the correct one, there is always a good chance that the man with a different opinion may have something meritorious to propose on his side. A story is told of Al [Alfred E.] Smith who was traveling in upper New York State with two companions, a Protestant and a Catholic. It was early on a bitterly cold Sunday morning when the two Catholics arose to attend mass. Looking at the Protestant sleeping peacefully in his warm bed, Al Smith said to his friend: "Wouldn't it be awful if he were right and we were wrong!"

The chance that the other fellow may be right, or partly right, makes it inadvisable to strive for unanimity of thought and opinion. Tolerance of diversity is necessary for the preservation of the spirit of free inquiry which is the breath of life of an institution devoted to education and research. Such tolerance is one of the main features distinguishing a democratic from a totalitarian society.

As indicated above, this concept is applied in the Institute's educational practices. In all courses, whether they are offered to undergraduates or graduates, the Department of Economics and Social Science tries to present contrasting views and opinions. In the beginning course in Economic Principles, which has been required of all students at the Institute, this procedure is subjected to severe time limitation. But even here this practice is followed. For several years we have been using supplementary readings presenting divers points of view and a new collection of such readings to accompany the textbook has just been prepared – a compilation that includes extracts from economic writings of all sorts, ranging from Karl Marx to the National Association of Manufacturers.

Besides this course in Economic Principles, there are many others, both on the undergraduate and the graduate level. These include several in the fields of labor relations, statistics, finance, theory, and in-



ternational economics. There are courses in business cycles, technological innovation, and in the economics of particular industries. The Department also offers courses in psychology and international relations. As the name implies, the Department of Economics and Social Science is one that covers a wide field. It is a part of the School of Humanities and Social Studies and has close ties with the activities of historians and others who come under the same administrative direction. The bringing together of a number of different social studies exerts a broadening influence on both staff and students. It tends to make us look at human beings as members of an ever-changing, complex society subject to many influences in addition to those of an economic nature.

Virtually every student at the Institute takes economics at some point in his program. In addition to those subjects included in the Humanities Program, designed for the Institute as a whole, other subjects are tailored to fit the needs of professional courses such as those offered by the Department of Business and Engineering Administration. The Department also offers a four-year curriculum for undergraduates – Course XIV – leading to a bachelor's degree in Economics and Engineering. Through emphasis on relationships among engineering, economics, and human relations problems, this Course aims to provide students with an understanding of both technical and nontechnical aspects of our industrial society.

There is also a graduate division. There are about 50 students in this group, most of whom are candidates for the Ph.D. degree. Many of these men have come to M.I.T. from liberal arts colleges. They go into government, business, labor unions, and teaching as professional economists.

Because the training of the professional economist, normally requiring about seven years, is spent mainly in the classroom and the library, his knowledge of actual business practices is more limited than if he were actively employed in industry. This limitation of experience is a handicap of which the men on the Department's staff are acutely conscious. We do not have as much direct contact, as might be desired, with what goes on in the factories, banks, railroads, public utilities, and other business enterprises whose activities we study.

Efforts are being made to bridge the gap between economic theory and business practice. Graduate students are encouraged to find summer employment in industry. Some of the staff members have had temporary jobs in business or government. Others have had an opportunity to get into close touch with industry through research projects. In recent years they have undertaken investigations in textiles, shoes, coal, housing, electronics equipment, and a variety of other industries. Several of our instructors act as consultants to business firms and have had ample opportunity to rub shoulders with businessmen and get a better idea of their operations and problems.

The Department also brings in businessmen to meet with classes and join in round-table discussions. The system of Visiting Committees is also helpful in getting the staff into touch with leaders in industry, finance, and the professions. But more of these contacts are needed. If we are to keep our feet on the ground, we must have the counsel and criticism of men of practical affairs.

The development of the new School of Industrial Management should be of material assistance in strengthening our contacts with leaders in the business world. Though the Department of Economics and Social Science will not be administratively a part of this School, it will be housed in the same building and will co-operate in carrying out its educational and research program. E. P. Brooks, '17, Dean of the School, who is now in charge, is consulting with business leaders and hopes to enlist their aid not only in planning the project but also in executing the plans. The Department of Economics and Social Science should benefit, at least indirectly, from these extensive outside relationships.

We are grateful to the Alumni and other friends of the Institute who have taken an interest in our work. The Department is indebted to the companies which have supported our Industrial Relations Section, and have helped finance graduate fellowships and research activities; it hopes for a continuation of this interest and support. Such support will be needed if the Department is to maintain its position and to improve and expand its operations.

The number of students being graduated from Course XIV is now relatively small, and the demand for their services is high; but in the future we hope to increase the enrollment, and employment conditions are not likely to continue as favorable as they are today. This Course is new and therefore not yet widely known. Because it combines basic education in engineering and science, as well as in economics, and other social studies, its graduates have a broad

(Concluded on page 320)

THE INSTITUTE GAZETTE

PREPARED IN COLLABORATION WITH THE TECHNOLOGY NEWS SERVICE

Center for International Studies

To meet the growing need for an intensive study of world affairs in the fields of social, political, and natural sciences, as well as in economics, the Center for International Studies has recently been established at M.I.T. In making this announcement, Julius A. Stratton, '23, Vice-president of the Institute, also stated that Professor Max F. Millikan, of the Department of Economics and Social Science, had been appointed director of the new program.

It is hoped that this program, by seeking the source of international problems, will lead to a better understanding among the peoples of the world. Although primary interest will be focused on studies of an international scope, attention will also be devoted to domestic problems arising from the increasing obligations of the United States in global affairs. The Center will concentrate on studies which, while of basic scientific and academic nature, are pertinent to specific contemporary problems facing the country.

Dr. Millikan attended the California Institute of Technology and Yale University, receiving his bachelor of science degree from Yale in 1935. Following his graduation from Yale he studied in England at Cambridge University. Dr. Millikan was appointed an instructor in economics at Yale in 1938 and received his Ph.D. in 1941. He was appointed assistant professor of economics in 1941. During World War II, Dr. Millikan served as a research consultant to the Office of Price Administration; assistant director, Division of Ship Requirements, War Shipping Administration; and as chief economist, Intelligence Branch, Division of Research for Europe, State Department. Dr. Millikan returned to Yale in 1946 as a research associate. He was appointed associate professor of economics at M.I.T. in 1949, and professor of economics in February, 1952. For the past year he has been on leave of absence to the government.

Dr. Millikan is a member of the American Economic Association, Econometric Society, Royal Economic Society, Institute of Mathematical Statistics, and the American Statistical Association. He is the editor and coauthor of a forthcoming book on income stabilization in a developing democracy.

Executive Assistant

THE appointment of Malcolm G. Kispert, 2-44, as Executive Assistant to the President of the Institute, has been announced by James R. Killian, Jr., '26, President of M.I.T. Mr. Kispert, who has served as administrative assistant to the president since 1946, was graduated from M.I.T. in 1944. He entered the Navy immediately after his graduation and served in the Pacific area, particularly the Hawaiian Islands, as an aviation engineering officer. Upon his return to M.I.T. in 1946, he was appointed to the administrative staff of the President's Office to assist Karl T. Compton, now chairman of the Corporation, and then Dr. Killian, the Institute's President since 1949.

Mr. Kispert was born in Fall River in 1923, received his early education at Durfee High School in that city, and entered M.I.T. in the autumn of 1940. He enlisted in the United States Navy in the fall of 1942, continuing his studies in uniform under the V-12 unit at M.I.T., and received the degree of bachelor of science in January, 1944. From January to September, 1946, he took graduate courses in Aeronautical Engineering and was awarded the degree of master of science.

M.I.T. Photo

Max F. Millikan . . . . . *Professor of Economics at M.I.T., has recently been designated as director of the Institute's newly established Center for International Studies. Julius A. Stratton, '23, Vice-president, and John E. Burchard, '23, Dean of Humanities, represent M.I.T. on the Advisory Board of the Center for International Studies, along with Paul H. Buck, Provost, and Edward S. Mason, Dean, of Harvard University, and Henry M. Wriston, President of Brown University.*

. . . . . **Malcolm G. Kispert** *has recently been named executive assistant to the president, after having been on the administrative staff of the President's Office for the past six years.*

M.I.T. Photo

Class Reunions

Plans for class reunions and get-togethers, to be held in conjunction with Alumni Day on Monday, June 9, and on other dates, are being formulated. The dates and places given below have been selected by the classes here listed whose members expect to hold gatherings this June.

1892 Tentative plans for luncheon or dinner to be held near Boston. Charles E. Fuller, reunion chairman, Box 144, Wellesley 81, Mass.

1897 June 9. Luncheon. Time and place not yet determined. John A. Collins, Jr., reunion chairman, 20 Quincy Street, Lawrence, Mass.

1900 June 10–12. The Pines, Cotuit, Mass. Elbert G. Allen, Secretary, 11 Richfield Road, West Newton 65, Mass.

1902 June 6–8. 50th reunion at Coonamessett Ranch Inn, North Falmouth, Mass. Claude E. Patch, reunion chairman, 862 Park Square Building, Boston 16.

1907 June 24–26. Oyster Harbors Club, Osterville, Mass. Bryant Nichols, reunion chairman, 23 Leland Road, Whitinsville, Mass.

1912 June 6–8. Snow Inn, Harwichport, Mass. Albion R. Davis, 11 Vane Street, Wellesley 81, Mass., and Ernest W. Davis, 6 Chapman Street, Arlington 74, Mass., are the reunion cochairmen.

1916 June 6–8. Coonamessett Ranch Inn, North Falmouth, Mass. Ralph A. Fletcher, Secretary, P. O. Box 71, West Chelmsford, Mass.

1917 June 6–8. Wentworth by the Sea, Portsmouth, N. H. Stanley C. Dunning, reunion chairman, 105 Irving Street, Cambridge 38, Mass.

1921 June 9. Class get-together in afternoon at Hotel Statler on Alumni Day.

1922 June 6–8. Sheldon House, Pine Orchard, Conn. Raymond C. Rundlett, reunion chairman, 6 Vine Street, Bronxville, N. Y.

1923 June 9. Class get-together at 5:00 P.M. at Hotel Statler on Alumni Day.

1927 June 6–8. 25th reunion at Oyster Harbors Club, Osterville, Mass. Glenn D. Jackson, Jr., reunion chairman, 54 Lenox Road, Summit, N. J.

1932 June 6–8. Curtis Hotel, Lenox, Mass. Thomas E. Sears, Jr., reunion chairman, Park Square Building, 31 St. James Avenue, Boston 16.

1937 June 6–9 (morning of Alumni Day). Weekapaug Inn, Weekapaug, R. I. Philip H. Peters, reunion chairman, 14 Cushing Road, Wellesley Hills 82, Mass.

1942 June 7–8. Hotel Griswold, New London, Conn. Charles A. Speas, reunion chairman, 17 Crown Ridge Road, Wellesley 81, Mass.

1947 June 6–8. Cliff Hotel, Scituate, Mass. James L. Phillips, reunion chairman, Masconomo Street, Manchester, Mass.

For additional information and the latest details please consult the class secretary or the reunion chairman, so that you may make satisfactory arrangements for attendance at your reunion.

Price Named Term Member

GWILYM A. PRICE, President of Westinghouse Electric Corporation since 1946, has been elected to term membership on the Corporation of the Institute until June, 1956, according to President Killian.

Born in Canonsburg, Pa., Mr. Price received his bachelor of laws degree from the University of Pittsburgh in 1917 and was admitted to the Pennsylvania bar in the same year. He practiced law in Pittsburgh after serving in World War I as a captain, 302 Heavy Tank Battalion, United States Army.

From 1920 to 1922 he was assistant trust officer at the Pittsburgh Trust Company, and from 1922 to 1943 he was associated with the Peoples-Pittsburgh Trust Company, successively as trust officer, vice-president, vice-president in charge of trusts, and president and director. In 1943 he became vice-president of the Westinghouse Electric and Manufacturing Company. Mr. Price is also a trustee or director of a number of bank, business, and insurance companies and a member of prominent professional and social clubs.

Council Doings

CONTINUING the trend of high attendance which has marked all Council meetings of the current year, 115 members and guests were present at the 287th meeting of the Alumni Council which was called to order by Alfred T. Glassett, '20, President of the Alumni Association, on February 25 in the Campus Room of the M.I.T. Graduate House.

Raymond Stevens, '17, offered the recommendations of the Committee on Resolutions for the late C. Adrian Sawyer, Jr., '02, which were unanimously adopted by a silent rising vote. C. George Dandrow, '22, has been named to fill the unexpired term of Mr. Sawyer on the Audit and Budget Committee.

As an item of business reported by Donald P. Severance, '38, Alumni Secretary, the Council learned that 26 members of the Institute's Faculty or staff visited 21 alumni clubs between January 8 and February 20 – from San Juan to Bangor, and from Seattle to Los Angeles.

The Executive Committee endorsed the following persons to serve on committees for Alumni Day which, this year, will occur on Monday, June 9: George Warren Smith, '26, general chairman; George W. McCreery, '19, cochairman; *Banquet Committee:* William H. Carlisle, Jr., '28, chairman, Donald W. Kitchin, '19, Clarence R. Westaway, '33, Robert M. Becker, '34, Russell Hastings, Jr., '34, Rogers B. Finch, '41, Richard J. Zeamer, '43, Albert B. Van Rennes, 10–44, Harl P. Aldrich, Jr.,' 47, and Stanley J. Marcewicz, '51; *Luncheon Committee:* Theodore T. Miller, '22, chairman, Alan W. Burke, '20, George W. Knight, '24, Chenery Salmon, '26, Frederick B. Grant, '39, Oswald Stewart, 2d, '39, John L. Danforth, '40, Theodore P. Heuchling, 2–46, and Donald A. Hurter, 6–46; *Committee on Departmental Reunions:* Julius A. Stratton, '23, chairman, Kenneth R. Wadleigh, '43, and Norman C. Dahl, '50; *Ladies' Events Committee:* Mrs. John B. Wilbur, chairman, Mrs. Walter H. Gale, Mrs.

Murray P. Horwood, '19, Mrs. Ralph T. Jope, Mrs. James R. Killian, Jr., Mrs. Robert M. Kimball, Mrs. George W. McCreery, Mrs. Theodore T. Miller, Mrs. George Warren Smith, Mrs. Avery H. Stanton, and Mrs. Julius A. Stratton; *Registration Committee:* Wolcott A. Hokanson, Staff, chairman, G. Edward Nealand, '32, and Robert E. Hewes, '43; *Transportation Committee:* Emmons J. Whitcomb, '11, chairman, and Malcolm S. Stevens, '34.

Henry B. Kane, '24, Director of the Alumni Fund, in his progress report mentioned that we have now passed the halfway mark of our solicitation year. Two additional mail solicitations are to be made: one now in progress; the last, in May. The total contributions of $131,500 represent about 60 per cent as many contributors as last year's final total and 80 per cent of the final amount. The present average contribution of $23 is the highest of any year.

The evening program opened with remarks from President Killian and Dr. Compton. President Killian specifically mentioned the dinner (held on February 15) of the M.I.T. Club of New York at the Waldorf Astoria where a New York Club award of a silver stein was presented to Lester D. Gardner, '98. To illustrate the Institute's needs for additional scholarship endowment, President Killian discussed the three figures of average scholarship aid per student enrolled; $33 for engineering schools; $55 for M.I.T.; $123 for liberal arts colleges. And, lastly, President Killian read a letter from the Superintendent of the Boston State Hospital mentioning the work done at the hospital by the pledges from one of the fraternities in lieu of the conventional Hell Week practices.

Dr. Compton spoke interestingly of the type of problems that come to him in the course of a day. He closed his remarks by praise of the extraordinary diligence of those who had been charged with the responsibility of selecting a new Dean of Students, spoke of the qualifications which had been required, and cited unanimity of opinion behind the selection of E. Francis Bowditch as Dean of Students, introducing Dean Bowditch as the next speaker.

Dean Bowditch spoke of his impressions of the responsibilities of the Dean's Office at M.I.T. and of the challenge of individualizing the process of bigness in our own educational institution. In particular, he referred to the inclusion of spiritual education as part of the education of the whole man and cited many examples indicating a growing sense of responsibility for the well-rounded education of the M.I.T. undergraduate.

The final speaker was Professor Charles S. Draper, '26, Head of the Department of Aeronautical Engineering, who spoke about automatic control of aircraft, including guided missiles. Following the trend for aircraft to be built with less and less dependence upon human supervision, Professor Draper predicted that automatic control of aircraft would leave the pilot with less and less to do in the future. He also discussed the problem of automatic control from the point of greater safety. Professor Draper concluded by referring to the need in the future for training aeronautical engineering students to think in terms of instrumentation of aircraft as well as the conventional structures, aerodynamics, and power plant.

Donald C. Stockbarger: 1895–1952

DONALD C. STOCKBARGER, '19, Associate Professor of Physics at M.I.T., died at his home in Belmont on February 23. Professor Stockbarger was internationally known for his development of the first optically usable laboratory-grown fluoride crystals ever obtained. He also developed apparatus and a method for growing oriented sodium nitrate crystals of optical quality.

Born in Walkerton, Ind., on October 19, 1895, Professor Stockbarger received the degree of bachelor of science from the Institute in 1919 and the degree of doctor of science in 1926. He joined the Department of Physics as an assistant in 1920 and became an instructor in 1923, an assistant professor in 1927 and an associate professor in 1935.

In the past Dr. Stockbarger has delivered lectures under the auspices of the Society of Arts at the Institute and contributed valuable articles in the pages of The Review. He was a fellow of the American Academy of Arts and Sciences.

Sloan Fellowships

PLANS for a nationwide competition for 14 Sloan Fellowships, entitling recipients to participate in the executive development program at the Institute, have been announced by E. P. Brooks, '17, Dean of M.I.T.'s new School of Industrial Management.

The fellowships are awarded to outstanding young executives under a program which was established more than 20 years ago by grants from the Alfred P. Sloan Foundation. The program covers a year of advanced study in economics and business administration at the Institute to prepare men for higher executive responsibility.

In announcing the 1952 fellowships, Dean Brooks said:

> This executive development program offers unusual opportunities for supplementing the practical industrial experience in the development of unusually able young men towards positions of higher responsibility in industry. This program, initiated at M.I.T. over 20 years ago, will now become part of our new School of Industrial Management. This school, made possible by a generous grant of funds from the Alfred P. Sloan Foundation, Inc., represents a substantial expansion in M.I.T.'s service in developing leaders for the benefit of industry and our total industrial society. We find that men already tested and tried in industrial experience can benefit to an unusual degree from an opportunity to broaden their understanding and to re-evaluate their own viewpoints concerning the complex problems facing industry today.

Nomination by an employer is a prerequisite of application for a Sloan Fellowship, since employers co-operate in the program both by sponsoring outstanding young men and by providing successful candidates with a year's leave of absence. Fellows are drawn from both large and small companies in various types of industry. They will participate in a special program of seminars, classes, and field investigations aimed at increasing their technical managerial skills, and at deepening their understanding of the social and economic implications of their work.

Adapting Mechanics to Change

THE Visiting Committee on the Department of Mechanical Engineering* met on December 15, 1950, under the chairmanship of Frederick S. Blackall, Jr., '22. The morning was devoted to visiting the metal-cutting and machine-tool laboratories; the afternoon and evening to discussions of departmental problems. The Committee commended in highest terms the work of the Department. It was especially impressed with the forward-looking attitude of Professor C. Richard Soderberg, '20, Head of the Department of Mechanical Engineering, and his associates.

During its 1949 meeting, the Committee had given extended consideration to the lack of sufficient choice in the professional electives for seniors. To meet this objection, a modification of the curriculum, in two stages, has been effected. The first stage, starting with the academic year 1951-1952, will provide for approximately 54 units of elective time in the fourth year of study.

The professional electives have been arranged in a large number of preferred groupings, designed to illustrate basic principles and methods of thought, and to arouse a maximum of enthusiastic interest on the part of the student. Certain of the professional subjects, such as Metals Processing 3.12, Strength of Materials 2.081, and Heat Engineering 2.43, will be mandatory only if included in one or another of the elective groups. Pursuant to recently promulgated Institute policy, opportunity will also be afforded for additional elective subjects in the humanities. The new elective system will make it possible for Course II students to give added attention to management problems, and will also facilitate the introduction from time to time in the future of new professional fields, such as nuclear power.

The second stage of transition concerns the second and third year curricula. Effective in the academic year 1952-1953, the requirements in Applied Mechanics and Fluid Mechanics will be reduced, thereby restoring the balance between these subjects and Thermodynamics. The second term of Machine Tool Laboratory 2.852 will be moved into the third year, when a more mature professional presentation can be made. The new curriculum also includes additional material in the form of a synthesis of electrical and mechanical engineering subjects, more effectively merging the two points of view.

The Committee was much interested in the Department's new plan for laboratory instruction. A generation ago, the Steam Laboratory occupied a preeminent place in the curriculum. Instruction was focused almost wholly upon the subject of power, then relatively new and vital. Industrial trends of the past 20 years have reduced the typical laboratory course to small dimensions; too often the latter has threatened to degenerate into a superficial coverage of outmoded subjects through stereotyped exercises. This challenge to effective laboratory instruction has been met through inclusion in these courses of up-to-date material, confronting the student with problems of current interest which will develop skill and judgment in the application of engineering measurements of present-day importance. The Committee supports these developments and anticipates promising results.

In co-operation with the School of Architecture, and the Department of Business and Engineering Administration, the Mechanical Engineering Department inaugurated experimentally a course in Industrial Design, intended to acquaint the student with some of the basic tenets of this field of engineering activity. Regular classroom instruction has been supplemented extensively by outside lecturers selected from active leaders in the field. The students' response to this program has been outstanding. Inaugurated as one phase of the revitalization of instruction in Machine Design, which has been in process for some time, this new course will broaden that field to embrace commercial, aesthetic, and production factors.

The Co-operative Course in Mechanical Engineering, known as II-B, has been functioning since 1948 and the Committee is gratified with the results obtained thus far. In 1950 about one quarter of the junior class was enrolled in this program, which seems to meet particularly well the needs of mechanical engineering students. The Committee has followed this development with much interest and emphasized the advantages of the six months' uninterrupted tour of duty at the plant in contrast with the three months' summer job.

The Committee considered at some length the relative significance of graduate and undergraduate work. During the past decade, the number of graduate students in Mechanical Engineering has approximately doubled, but this is but an inadequate index of the real growth of the Department in the field of post-graduate instruction. The graduate student of today has vastly greater opportunities than those of his counterpart, 10 years ago. By way of example, consider the growth of research in the field of materials, where the program is now unusually extensive and includes joint activities with the Department of Metallurgy in Metals Processing.

Up to the present time, it has been relatively easy for the Department to enroll superior students in the Graduate School, but this situation may change as the Defense Program develops. While the Committee does not recommend any change in the relative emphasis on graduate and undergraduate activities, it does believe firmly and unequivocably that our educational standards must be maintained on the highest plane for the undergraduate, as well as the graduate, school.

The Committee felt that the steps which have been taken toward the improvement of the curriculum represent real progress in the direction of the ideal program for complete and well-rounded training of the engineers of the future. The task is to adapt Mechanical Engineering instruction to changing conditions and requirements without ever losing sight of the importance of fundamentals. The Committee believed that responsibility for this task was in strong hands in the Mechanical Engineering Faculty.

(Concluded on page 312)

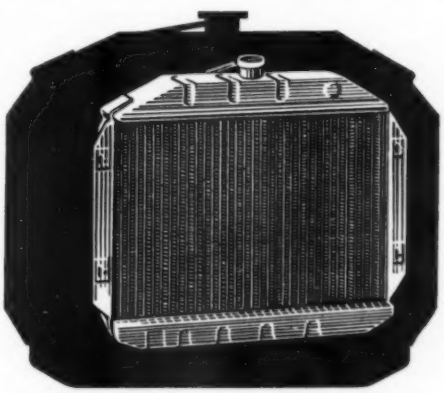
* Members of this Committee for 1950–1951 were: Frederick S. Blackall, Jr., '22, chairman, Redfield Proctor, '02, Andrey A. Potter, '03, Max L. Waterman, '13, Thomas H. West, 3d, '22, Alexander C. Monteith, and Lewis K. Sillcox.

BUSINESS IN MOTION

To our Colleagues in American Business . . .

Substitution of materials is of considerable concern to many manufacturers these days. Never before have we seen so much interest in the subject. However, it is by no means new to Revere, which has always held to the principle of recommending the metal that will best serve the customer. Thus, we have often suggested switching from one metal or alloy to another, with the object of lowering costs, increasing production, improving service, or all three.

When based on a detailed study of all the factors involved, substitution at times can be extremely valuable. In fact, the ever-increasing quality and service to be found in American products is due in part to the continued search for better materials, and their adoption when found. Better materials, better design, finer workmanship—these are part of American progress.



But there are instances, of course, when no practical substitute can be found, when only one material offers just the right combination of good qualities required for a given application. Take the automobile radiator. This has always been made of copper, because copper is the one and thus far only metal that perfectly meets all the requirements of manufacture and service. To make a radiator, very thin copper sheet and strip must be crimped, bent and otherwise formed. Copper's easy workability makes it ideal from the manufacturing standpoint. After assembly, the radiator is cleaned, and made water-tight by dipping in a bath of hot solder. Copper is exceptionally easy to solder. When in service on a car, truck or bus, the radiator must not rust, and must resist corrosion by water and anti-freeze. Copper is notable for its resistance to corrosion in such use. The radiator must also cool the water by radiating its heat into the air stream; copper has the highest heat conductivity of all commercial metals. A copper radiator thus is the most efficient and durable. It should outlast the car unless accidentally damaged, and when the injury is not so great as to make replacement necessary, the nearest shop can make repairs easily.

Recently it has been suggested that automotive radiators should be made of aluminum. However, both copper and aluminum are temporarily in short supply, and therefore to substitute one for the other does not appear to be practical. Beyond that, we do not believe —based upon experience to date—that aluminum's qualities, fine though they are, necessarily make it suitable for automotive radiators. In addition, the difficulties of retooling in the factory and repairs in the field must be considered. Revere fabricates both copper and aluminum, and we have reason to believe that our impartial advice to stay with copper for automotive radiators is concurred in by radiator manufacturers.

When you are tempted to substitute one material for another in your product, no matter what it may be, make certain you obtain all the facts as to costs, production, service. Your suppliers will be glad to collaborate with you in studying the effects of a proposed change. We suggest you take full advantage of their knowledge and experience.

REVERE COPPER AND BRASS INCORPORATED

Founded by Paul Revere in 1801

Executive Offices: 230 Park Avenue, New York 17, N. Y.

SEE "MEET THE PRESS" ON NBC TELEVISION EVERY SUNDAY

THE INSTITUTE GAZETTE

(*Concluded from page 310*)

Flight Control

THE Visiting Committee on the Department of Aeronautical Engineering* met on May 7, 1951, and discussed the problems and activities of the Department with Professor Jerome C. Hunsaker, '12, and his staff. Although all members of the Committee were not unanimous in their views, the Committee made the following recommendations:

1. The Committee noted the difficulties of including, in a four-year undergraduate course for all, the subjects required to keep pace with modern aeronautical engineering developments and suggested that the four-year undergraduate course should be retained and that a five-year course should be provided for students who are financially able to take it.

2. The Committee recommended that the humanities should have a position of importance in engineering education, but where conflicts exist, priority should be given to professional subjects.

The Committee recommended that additions be made to the curriculum as follows: (a) Studies to cover instrumentation necessary for the control of new types of high-speed aircraft and guided missiles, since such instrumentation has now become an integral part of their design; (b) The study of armament, which is an integral part of the design of aircraft for military purposes; (c) The study of helicopter and other rotary wing aircraft, which now constitute one of the major developments in aviation.

4. The Committee stressed the desirability of following the careers of the Department's graduates and preparing statistical data on the numbers who follow careers in various fields.

5. The Committee felt that there is a great need to attract competent engineering talent in Ground Aviation, which comprises airport design, ground navigational aids, communications, and the handling of passenger and cargo traffic.

The Committee was greatly impressed with the method of teaching instrumentation under Professor Charles S. Draper, '26, where it is the practice to give the students problems involving theoretical analyses of systems being experimented with in the laboratory.

* Members of this Committee for 1950–1951 were: Luis de Florez, '11, chairman, Theodore P. Wright, '18, Frederick S. Blackall, Jr., '22, James H. Doolittle, '24, George J. Leness, '26, Preston R. Bassett, and Leroy R. Grumman.

NEW FRONTIERS IN SCIENCE

(*Continued from page 296*)

each did his essential part in the complex program of a modern technological development. What is new in our lifetime is the wherewithal to benefit from science. Especially important are the teams of competent specialists who can carry out the research, development, engineering, and pilot-plant operations, and provide the management skill for the organized effort. Dr. Fleming's discovery of penicillin would probably have meant little to human welfare if it had been made in 1850.

As another illustration of the mechanics of the process of utilizing science, consider the spectacular development of nuclear energy. This was an outgrowth of the work of both theoretical and experimental physicists, and stemmed largely from the discoveries of the 32-year period from 1887 to 1919. It was not until January, 1939, however, that Hahn discovered the formation of barium by the neutron bombardment of uranium. Recognized as nuclear fission by the refugee scientists, Frisch and Lise Meitner, the news of the German experiment was brought to this continent by Niels Bohr. Experimentally, nuclear fission was confirmed in four laboratories in three countries within a month of the first experiment in Berlin. The bomb development race was on.

The wartime history of the bomb project has been well described, in outline, if not in detail. Many scientists in Britain, Canada, and the United States were brought together to solve the remaining problems. Engineers designed processes for winning uranium from its ores. Teams of scientists and engineers developed methods for the separation of uranium isotopes, and engineers built the fabulous K-25 plant at Oak Ridge for this purpose. New towns were built and the plants were guarded by small armies. The two billion dollars spent to get the first few atom bombs indicates the magnitude of the undertaking. The complexity of organization and planning can hardly be imagined. Except for the invasion of Normandy, man has perhaps never in history completed such a large and complex undertaking.

Again my point is the powerful new tool – teamwork – which we have developed, in our time, for the purpose of utilizing scientific discoveries for something we think worth-while. Science, engineering, and production, working together, do what any one of the three would find impossible.

I know many brilliant and productive scientists, but I am not convinced that scientists as a group are more intelligent than other professional or business people. But scientists are peculiarly important in the scheme of things because the whole development process waits on their initial performance. They push the button that starts the machine. No Fleming, no penicillin – no matter how competent others may be. Because of this, it seems strange that industry does not provide more support for basic science.

The engineers and the rest of the team have learned to do a lot with a few scraps tossed by the scientist, and have seen some lean years. Faraday and Maxwell laid the basis for our electrical industry, but electrical engineers had to be content with little that was new until electronics began to develop two or three generations later. In the intervening 50 years, the electrical engineer, with nothing much more than Maxwell's equations, a few data on properties of materials, and a slide rule succeeded in developing our

(*Continued on page 314*)

Establishing new standards of POWER AT SEA

Highest Steam Temperature
The S.S. Atlantic Seaman is one of three such ships of the Atlantic Refining fleet

Highest Steam Pressure
The S.S. Venore is one of eight such ships of the Ore Steamship fleet

The largest and fastest commercial tankers yet built in this country are the three placed in service during 1950-1951 by Philadelphia Tankers, Inc., a subsidiary of the Atlantic Refining Company. An especially notable feature of these ships is that their boilers are designed to produce steam at the highest temperature ever used in merchant marine service—1020 degrees Fahrenheit.

Another outstanding example of advanced power practice at sea is the fleet of eight ocean-going ore carriers operated by the Ore Steamship Company. This famous fleet, which maintains a regular schedule on an 8000-mile, round trip voyage between Sparrows Point, Maryland and Cruz Grande, Chile, is powered with the highest pressure boilers in marine service today—1450 pounds per square inch.

These new "highs" in steam temperature and pressure achieve lower fuel consumption per shaft horsepower for these eleven ships, all of which are equipped with boilers designed and built by Combustion. And these are just a few of the new ships equipped with C-E Marine Boilers that have gone down the ways in the years since World War II—ships that range from sea-going dredges to luxury liners—from the largest and fastest ore carrier on the Great Lakes to advanced designs of naval vessels.

It is no coincidence that Combustion's name, which long has been associated with notable advances in boiler designs for utility and industrial power stations, has attained a similar position in the field of marine power practice. Rather it is the result of a policy which seeks to anticipate the next forward step of progress and achieve its earliest possible application to practice. Thus you can be sure... whether your steam requirements are large or small... that a C-E Boiler will bring you truly modern design and performance.

ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT

COMBUSTION ENGINEERING—SUPERHEATER, INC.

B-542

Combustion Engineering Building
200 Madison Avenue • New York 16, N. Y.

BARNSTEAD DEMINERALIZERS

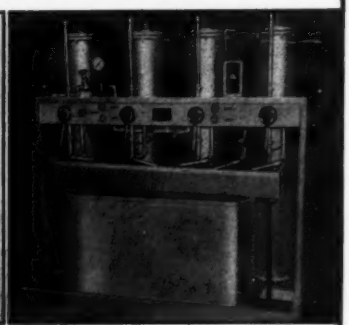
PROVIDE LOW-COST

PURE WATER

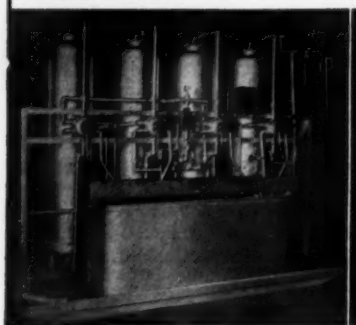
for • Electroplating • Anodizing
• Photographic Solutions
• Salt-free Rinse Water • Silvering

And Hundreds of Other Applications

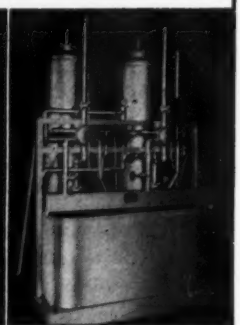
Barnstead Four-Bed Demineralizer provides pure water for hot seal tank in anodizing. 30 gal/h.



Four-bed Barnstead Demineralizer produces pure, sparkling-clear rinse water for pharmaceutical plant. 200 gal/h.



Four-bed Barnstead Demineralizer providing pure, high resistance water for electronic mfgr. 1000 gal/h.



Two-bed Barnstead Demineralizer. Used in large automotive plant. 1000 gal/h.

Selection of the best size and type of demineralizer for your operation depends on the nature of your raw water supply, flow rate needed, daily demand, and degree of purity required. Send a sample of your water to our Laboratory and Barnstead Engineers will perform the necessary analysis without obligation.

PROMPT DELIVERIES WRITE FOR FREE CATALOG

Barnstead
STILL & STERILIZER CO.
65 Lanesville Terrace, Forest Hills, Boston 31, Mass.

NEW FRONTIERS IN SCIENCE

(*Continued from page 312*)

great light, power, and communications industries. Now the electrical engineer has a new lease on life, by virtue of the new scientific discoveries in electronics, including the very recent transistor development, which may make the vacuum tube obsolete.

The importance of the team effort of scientists and industrial technologists raises the question of why industry does not feed and keep their own scientists, so that the team can work together in one place. To a certain extent industry does this, but primarily it employs applied scientists and technicians. Basic or pure science thrives best when left alone, progressing by a sort of Brownian motion, in random directions determined solely by the curiosity of the scientist. The profit motive in industry does not encourage the employment of men who are allowed to do whatever they please. The universities have had the wisdom to do this, and the results have been spectacular.

Even in the early days of the scientific revolution, when science was not quite respectable in academic circles, such great men as Galileo, Copernicus, Paracelsus, and Newton were all professors. Nearly all of the important contributors to basic medical science, biology, chemistry, and modern physics were professors. In pure or basic science, university science *is* science. With a few notable exceptions, such as the Rockefeller Institute for Medical Research, it has been the universities which have supported science and scientists, providing the freedom of inquiry so necessary to scientific progress. Russia is now repeating the medieval experiment of dictating what scientists shall believe. Such a policy provides a most hopeful sign that Russian technology will not be able to compete with ours.

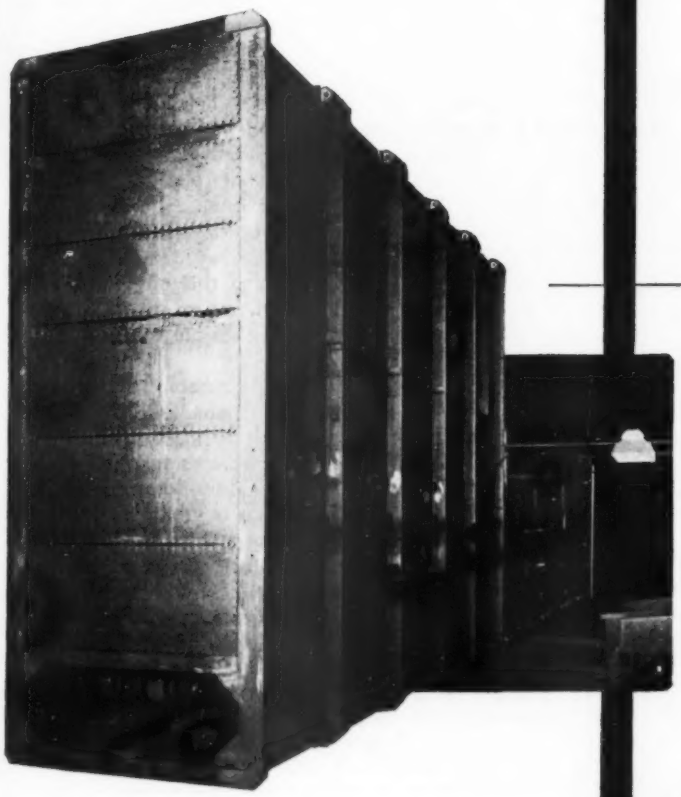
M.I.T. does not employ scientists in a sense of charity, but for the purpose of fulfilling its functions and obligations. These are the extension of human knowledge and the education of students. Even with inadequate research grants, first-class professors in science can hardly be kept away from research which extends human knowledge. Certainly they assist in the education of students in areas of increasing importance to everyday living.

But professors in the fields of engineering and science do something more which is extremely important. They are largely responsible for providing the creative atmosphere which is the university. Curricula confined to the teaching of facts, no matter how recondite the subjects, do not belong in universities. The research and creative activities of the staff, particularly in engineering and the sciences, give the student some sense of the thrill of creative accomplishment. I believe the creative atmosphere, and the ability to make students understand the meaning of creative accomplishment, are the basic differences between universities and the high schools.

Science – university science – has a proud record and clearly a brilliant future. It has provided man with the tools to do what he wishes to do, rather than what he is driven to do. It has removed the physical

(*Continued on page 316*)

LIQUID OXYGEN



High performance, low cost, and relative ease of storage and handling make liquid oxygen not only the best oxidizer available but guarantee it a prominent place among high performance oxidizers in the future.

Liquid oxygen has certain advantages when comparing oxidizers:

1. **A potential supply unlimited**
2. **Production possible at source**
3. **Inexpensive**
4. **Non-toxic, non-corrosive, smoke-free combustion products**
5. **Easily ignited and smooth burning**
6. **Few limitations on component materials of construction**
7. **Not affected appreciably by ambient temperatures**

Arthur D. Little recently designed and constructed an air-transportable plant for the separation of oxygen from air. This plant was designed to produce 10 tons of liquid oxygen per day.

Experience in the technology of producing, handling and storing liquefied gases aided the Mechanical Division of Arthur D. Little in the design of this plant where minimum weight, small size and purity of product were the prime objectives. The Mechanical Division has further used its experience with liquid gases to design and produce the ADL Helium Refrigerator which is for the storage of liquid gases to reduce evaporation loss to zero.

Although liquid oxygen is produced in wartime chiefly for use as a propellant it may also be used for welding operations and breathing aids when converted to gas by the ADL Liquid-Oxygen Pump.

ADL
Mechanical Division

ARTHUR D. LITTLE, Inc.
Mechanical Division
30 MEMORIAL DRIVE • CAMBRIDGE, MASS.

Send for catalog **TR-1**, describing these and other products and services of the Mechanical Division.

Precision Electric Heat Treat Furnaces *(Laboratory and Industrial)*

Dry Type Air Cooled Transformers *(to 1000 KVA)*

Constant Current Regulators *(Static Type)*

Many nationally known laboratories and manufacturing plants use Hevi Duty Electric Heat Treating Furnaces where maximum performance is desired.

Hevi Duty specialty transformers are used extensively in the electrical control of industrial machinery and plant power distribution.

Airport and street lighting have been made safer and maintenance costs have been reduced through the use of Hevi Duty static type Constant Current Regulators.

Write for descriptive bulletins

HEVI DUTY ELECTRIC COMPANY

HEVI DUTY

HEAT TREATING FURNACES • ELECTRIC EXCLUSIVELY
DRY TYPE TRANSFORMERS—CONSTANT CURRENT REGULATORS
MILWAUKEE 1, WISCONSIN

Harold E. Koch, '22, President
Elton E. Staples, '26, Vice President

NEW FRONTIERS IN SCIENCE

(Continued from page 314)

obstacles to ethical and spiritual progress. As Karl T. Compton, chairman of the M.I.T. Corporation, has written: "Science has given us, for the first time in the history of the human race, a way of securing the more abundant life without taking it from someone else or working inordinately hard and long to get it."

It has been said that the results of science are morally neutral, neither good nor bad; that man determines whether they be put to good or evil use. The problem of nuclear energy, of course, challenges our willingness to use science for good and not for ill. But science is nothing but knowledge, and we have the deepest faith that knowledge is good and ignorance evil. Handing nuclear energy to our modern race may be like giving a lighted Roman candle to a baby; the result could be disastrous. Perhaps we are not of sufficient moral maturity to handle the power which science has provided us, but we intend to have a good try at growing up fast enough to use this power for good.

Throughout the ages, man has held faith in the idea of progress, though the evidence of progress has often been nebulous. Science now provides us with some assurance of progress, and perhaps even some slight glimmer of our ultimate purpose. We know more about electricity than did Faraday, and more about the human body than did Harvey. Clearly we have more power over nature than did our forefathers. There seems to be real evidence of progress in this area, and the concept of progress has taken on tangible meaning.

Through science man feels humbled both by the complexity of natural phenomena and by the evidences of order, pattern, and purpose which he finds in nature. At the same time, he is inspired by the thought that he may ultimately learn everything about nature, that knowledge is good, and that the ills of mankind will disappear if there is sufficient knowledge. The scientist senses, perhaps, that if he knows all about nature he will come to know God.

In any case, we have science, and we could not stop the accumulation of knowledge if we tried. The idle suggestion that there should be a moratorium on science because it can be used for evil is like the idea that we should stop steel production because

(Concluded on page 318)

GEORGE W. McCREERY CO.

Building Construction

126 NEWBURY STREET BOSTON, MASS.

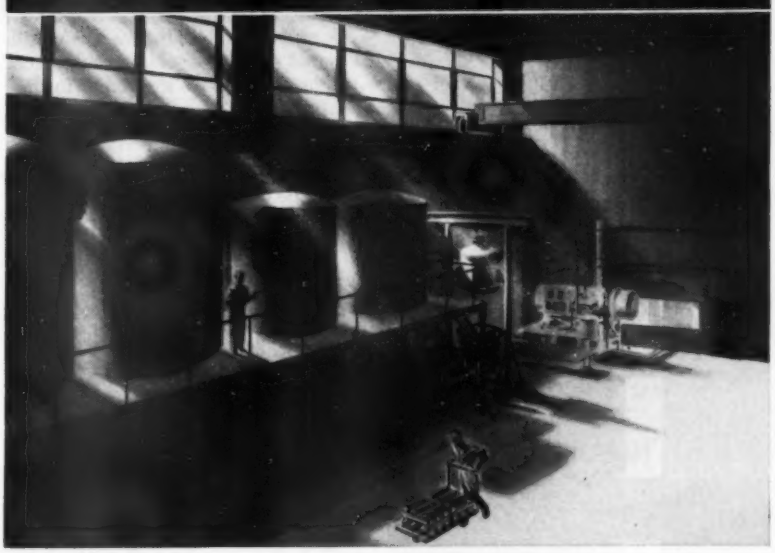
National Research Corporation

Announces

Another New Company
Born of Research

VACUUM METALS CORPORATION

U. S. A.'s Sole Commercial Source of Vacuum Melted Metals



Vacuum Metals Corporation has been formed to supply specialty metals and alloys for applications of high performance in terms of physical, chemical or electrical properties. Vacuum melting techniques developed by National Research are used to produce metals of higher purity and alloys held to closer composition tolerances than ever before achieved commercially.

Organized by National Research as a wholly-owned subsidiary, Vacuum Metals Corporation now has facilities for vacuum melting more than five tons per day of metals such as copper, nickel, molybdenum or iron.

Vacuum Metals Corporation joins the other companies created by National Research such as Minute Maid Corporation, the first to make quick-frozen orange juice concentrate, and Holiday Brands, Inc., the first to make crystalline soluble coffee.

New Enterprises Through Research

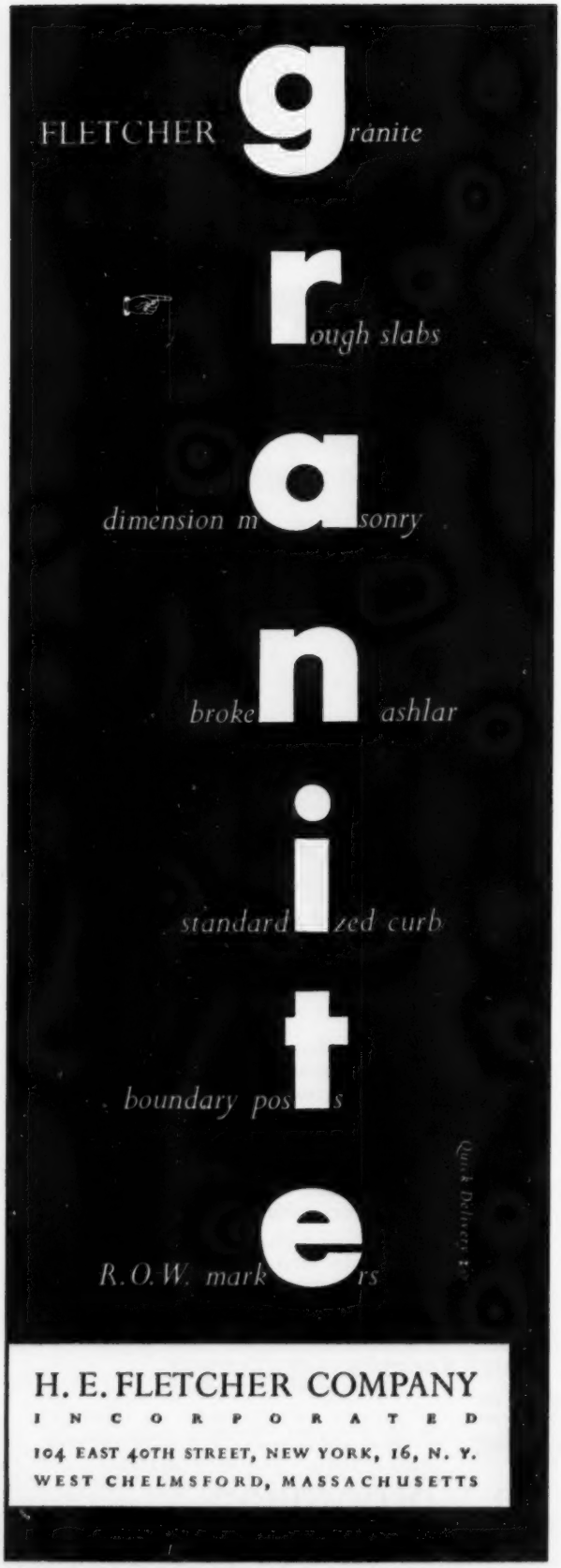
INDUSTRIAL RESEARCH · PROCESS DEVELOPMENT
HIGH VACUUM ENGINEERING AND EQUIPMENT

METALLURGY · DEHYDRATION · DISTILLATION
COATING · APPLIED PHYSICS

National Research Corporation

Seventy Memorial Drive, Cambridge, Massachusetts

In the United Kingdom: BRITISH-AMERICAN RESEARCH, LTD., Head Office — Wishaw, Lanarkshire



NEW FRONTIERS IN SCIENCE

(Concluded from page 316)

some steel goes into munitions. It is an affront to our intelligence, and to our faith that knowledge is good.

If the results of science are neutral, the methods of science are not without morality. Speaking of science and scientists, J. Robert Oppenheimer says the following:

> There is [in science] a total lack of authoritarianism, which is hard to comprehend or to admit unless one has lived with it. . . . In science the worker learns the possibility of error very early. He learns that there are ways to correct his mistakes; he learns the futility of trying to conceal them. . . . We [scientists] learn that views may be useful and inspiriting though they are not complete. We come to have a great caution in all assertions of totality, of finality or absoluteness. . . . We learn to throw away those instruments of action and those modes of description which are not appropriate to the reality we are trying to discern, and in this most painful discipline, find ourselves modest before the world. . . . If the professional pursuit of science makes good scientists, if it makes men with a certain serenity in their lives, who yield perhaps a little more slowly than others to the natural corruptions of their time, it is doing a great deal. . . .*

And finally, we have the words of Aristotle: "Search for the truth is in one way hard and another easy, for it is evident that no one can master it fully nor miss it wholly. But each adds a little to our knowledge of Nature and from all the facts assembled there arises a certain grandeur."

*"Physics in the Contemporary World," The Technology Review, **50**:201 (February, 1948).

TELEPHONE SERVICE

(Concluded from page 303)

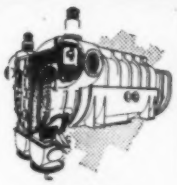
dormitory units. Upon receiving a call, the student goes to the nearest one of these corridor telephones, dials 0, gets the information operator, and asks for his call by name. Students make their outgoing calls from any one of the 42 conveniently located pay stations about the dormitories and the Institute.

In the near future, it is planned to install the fire alarm central office equipment in the room next to the switchboard. Upon hearing an audible signal indicating a box alarm, the chief telephone operator will read the box number and sound the fire alarm over the code call to alert the Institute's Buildings and Power people assigned to fire fighting.

Reporting of fire by telephone is to be done by dialing "100." This rings a bell in the Operating Room and causes a red lamp in the trunk multiple to light. The operator answers and talks with the person making the report, recording the details. The operator then operates the code call as in the case of a box alarm.

A brief statement of M.I.T's telephone traffic may be of interest. During recent months, these switchboards have been handling over 100,000 local calls a month and about 2,500 toll calls. The bill is currently running well over $200,000 a year, in addition to the salaries of operators and the cost of directories.

DID YOU KNOW?



1 . . . that you can Clean Condenser Tube Sheets without Downtime or Loss of Pressure?

C. H. Wheeler Reverse Flow Condensers are "Self-Cleaning". Electrically, hydraulically or manually operated sluice gates within the condenser reverse the flow of water in the tubes to flush debris and marine growth away from tube sheets.

2 . . . that there are Vacuum Pumps with No Moving Parts . . . and often requiring No Extra Power?

C. H. Wheeler Tubejets convert waste steam into useful vacuum for pumping, refrigeration, etc.

3 . . . that a Cooling Tower can be Built to Blend with a Building—or to Stand Alone against Hurricane Winds?

C. H. Wheeler Water Cooling Towers may be sheathed with any building material to harmonize with an architectural plan. Sturdy construction is guaranteed for performance and durability.

4 . . . that Material will Grind Itself into Particles 100 Times Finer than the Human Eye Can See?

C. H. Wheeler Fluid Energy Reduction Mills reduce materials to sub-micron particle sizes. Material is conveyed by air, steam or any gas or vapor in a closed circuit at supersonic speeds causing particles to reduce themselves by repeated shattering contact with one another.

Bulletins mailed on request.

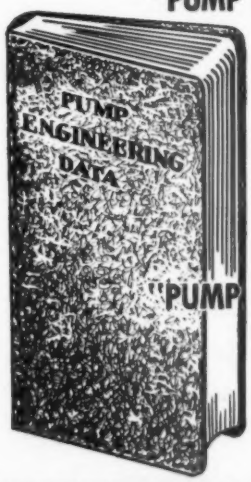
C. H. WHEELER MANUFACTURING COMPANY

19TH & LEHIGH AVENUE, PHILA. 32, PA.
DIVISION OF HAMILTON-THOMAS CORP.

Steam Condensers • Steam-Jet Ejectors • Cooling Towers • Vacuum Refrigeration • High Vacuum Process Equipment • Micro-Particle Reduction Mills • Marine Condensers & Ejectors • Deck Machinery

1952 PUMP ENGINEERING HANDBOOK

The Research Has Been Done For You



"PUMP ENGINEERING DATA" has been compiled for professional and student engineers who want their information in one volume. Designed for ease for use, with tables, diagrams, and charts.

"PUMP ENGINEERING DATA" was assembled by experts to provide the most pertinent and up-to-date material for pump engineering. Substantially bound in maroon and gold—contains over 400 pages.

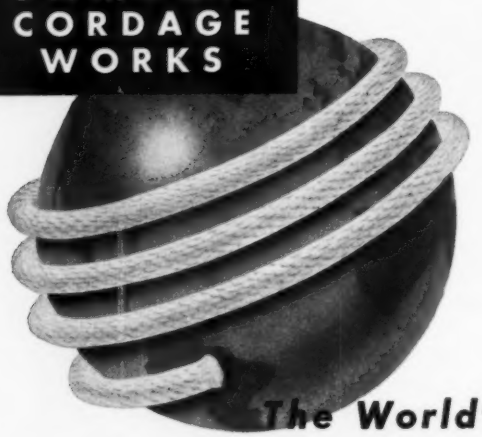
"PUMP ENGINEERING DATA" covers pumping problems encountered in buildings, waterworks, sewage treatment plants, oil refineries, mines and quarries, irrigation, power plants, food and chemical plants, paper mills, and in many other applications.

send today for your copy of **"PUMP ENGINEERING DATA"** $3.00

WHEELER-ECONOMY PUMPS

ECONOMY PUMPS, INC • Division of C. H. Wheeler Mfg. Co.
Sedgley at 19th and Lehigh • Philadelphia 32, Penna.

SAMSON CORDAGE WORKS



The World's Largest Manufacturers of Braided Cotton Cord!

A wide variety of Solid Braided and Hollow Braided Cotton Cords in sizes and qualities for many purposes.

For samples and information, write today.

Samson CORDAGE WORKS
Boston, Mass.

A Samson PRODUCT FOR LASTING ECONOMY

ECONOMICS AT M. I. T.

(Concluded from page 306)

background that should make them useful in a wide variety of jobs.

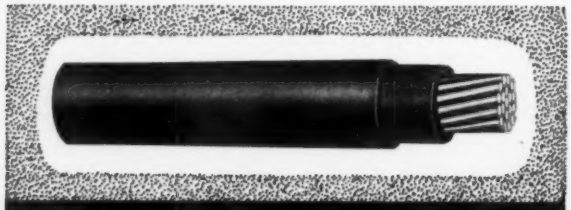
This spring the Department of Economics and Social Science expects to move into the recently acquired Sloan Building along with the School of Industrial Management. Readers of this article are invited to come and visit us in our new quarters. We will show you our Industrial Relations Library and our Psychological Laboratory. We will tell you about the Scanlon Plan that is making a valuable contribution to the betterment of employer-employee relations. We will describe research projects under way and point with pride to a growing list of publications by members of the Department. We would like to discuss with you the plans we have for future development in psychology and political science. The reader may be interested in meeting some of the staff or in talking to groups of students and if he can bear it, we will also tell him about some of our trials and tribulations. And perhaps he may have something on his mind he would like to tell us. If so, we will gladly listen. Our new address will be 50 Memorial Drive.

AUDIO ENGINEERING

(Continued from page 301)

by microphone placement and studio acoustics. Thus, the effective bass response will be raised by placing the double basses, cellos, and drums nearer the microphone, and a studio with excessive high-frequency reverberation will produce a shriller record regardless of what electrical system measurements show. For this reason, previous attempts to standardize recording have all foundered in practice. By using a technique which had previously answered a similar problem in the motion-picture industry, the Audio Engineering Society has recently found an answer. The idea is to standardize the response of the reproducing system so that any record which sounds good on this system, is, by definition, properly recorded. It is much easier to standardize reproducing systems rather than recording systems, and so the Audio Engineering Society's proposal of-

(Continued on page 322)



SIMPLEX ANHYDROPRENE CABLES

Lightweight, small-diameter cables that promise low-cost, trouble-free service as underground primaries and secondaries, as transformer leads and pole line risers, in signal and control circuits, and when used for plant and shop and instrument wiring.

Consist only of a coated copper conductor, Anhydrex insulation, and a thin neoprene jacket.

Anhydrex insulation assures high dielectric strength and exceptional stability in wet locations. The neoprene jacket provides protection against rough handling, oil, grease, corrosive chemicals, light and flame.

Get detailed information plus specification data by writing today for Bulletin 115.

SIMPLEX WIRE & CABLE CO.
79 SIDNEY STREET, CAMBRIDGE 39, MASS.

J. C. CORRIGAN CO., INC.
Conveyers
ENGINEERS · MANUFACTURERS · ERECTORS
•
Coal Handling Systems
Material Handling and Processing Equipment
Portable Conveyers
•
Distributors for
Jeffrey Manufacturing Co.
41 Norwood Street, Boston 22, Mass.
Tel. GEneva 6-0800

Advance Professionally FASTER

In Career-Building Positions at RCA

Career-minded engineers have found the way to more rapid advancement and professional development through challenging assignments at RCA, on long-range military *and* commercial projects.

RCA IS A GOOD PLACE TO WORK

At RCA you receive recognition for your accomplishments. You work in close collaboration with distinguished scientists and engineers. You enjoy highest professional recognition among your colleagues. You have unexcelled facilities for creative work. The surroundings in which you work are pleasant and stimulating. You and your family enjoy outstanding employee benefits. Opportunities are excellent for advancement in position and income.

DIVERSIFIED LONG-TERM PROGRAM

Positions open are *career* opportunities of a lifetime. They are not "emergency" jobs. They offer *lifelong* employment opportunities to men who expect more from their work than is provided by an ordinary engineering assignment. They cover not only revolutionary new military projects, but also trailblazing commercial projects for important electronic advances of the future. Such diversification of products and markets represent long-term employment opportunities independent of wars or depressions.

If you aspire to a career-building future, investigate the positions now open at RCA.

MAIL RÉSUMÉ

If you desire to consider any of the positions listed, write us for a personal interview—include a complete résumé of your education and experience. Send résumé to:

MR. ROBERT E. McQUISTON, Manager
Specialized Employment Division, Dept. 142 D
Radio Corporation of America
30 Rockefeller Plaza, New York 20, N. Y.

RADIO CORPORATION of AMERICA

CHOOSE YOUR FIELD OF SPECIALIZATION

Engineers **— ELECTRONIC • COMMUNICATION • ELECTRICAL • MECHANICAL • DIGITAL COMPUTER and PHYSICISTS**

Research • Development • Design • Application

TELEVISION DEVELOPMENT—
Receivers, Transmitters and Studio Equipment.

ELECTRON TUBE DEVELOPMENT—
Receiving, Transmitting, Cathode-Ray, Phototubes and Magnetrons.

COMMUNICATIONS—
Microwave, Mobile Aviation and Specialized Military Systems.

RADAR—
Circuitry, Antenna Design, Computer, Servo-Systems, and Information Display Systems.

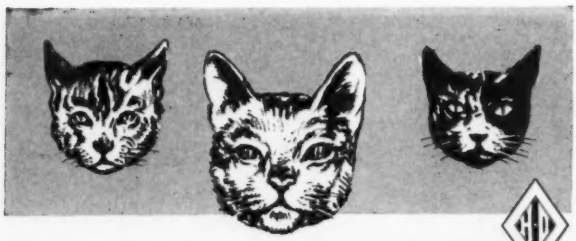
SYSTEMS PLANNING and DESIGN—
Missile Guidance, Radar and Fire Control.

SERVO MECHANISMS—
Instrument and Power Servos, Feedback Amplifiers and Power Supplies.

MECHANISMS—
Precision Power Gear Drives, Precision Instrument Gear Drives, Lightweight Shock and Vibration Structures to House Electronic Equipment, and Antenna Structures.

COMPUTER DEVELOPMENT and DESIGN
Digital and Analog Computers, Magnetic Recording, Pulse Circuitry, Storage Components, and Systems Design.

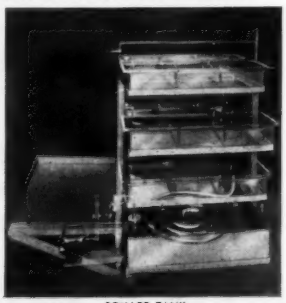
TRANSFORMER and COIL DESIGN
NAVIGATIONAL AIDS
TECHNICAL SALES
ELECTRONIC EQUIPMENT FIELD SERVICE



Not 9... but 10 LIVES

LONG LIFE IS A FEATURE OF H-D EQUIPMENT

Equally important is its low operating and maintenance cost. But these factors are incidental to the *performance* features that bring lowered manufacturing costs and better made products wherever installed. For twisting, bunching and stranding operations, H-D equipment assures consistent straight-break strength... stronger, ply for ply... uniformity of twist, free from broken ends—and many other advantages. Bulletins, available on request, explain H-D equipment in detail. Worth reading. Write for copies, outlining your manufacturing problems, TODAY.



SQUARE TANK

HASKELL-DAWES MACHINE CO., INC.
2231 E. ONTARIO ST., PHILADELPHIA 34, PA.

When You Call For Any Industrial Requirement In Piping

ALBERT
"Rings the Bell"

SPEEDLAY-PIPE SYSTEM—completely packaged for fast-laying temporary and semi-permanent lines for water, compressed air, and other services.

PILING—Sheet Piling—light weight Tubular—all sizes

PILE SHELLS—Spiral Welded, Hel-Cor, Riveted, CAISSONS

PILE FITTINGS—All types and sizes for steel and wood, cast steel and iron points. Plates and shoes cast steel and malleable iron sleeves.

CULVERTS—Corrugated, Spiral or Riveted Steel

VALVES AND FITTINGS—Tube turns, Dresser, Vitaulic, cast iron or steel, forged steel, special alloys, water main.

SPECIALISTS IN PRE-FABRICATED PIPING

ALBERT
PIPE SUPPLY CO., INC.
Berry at North 13th St.
Brooklyn 11, N. Y.
Phone EVergreen 7-8100

AUDIO ENGINEERING

(Continued from page 320)

fers a practical means of solving an old problem. This standard is actually the more logical of the two courses, for we want to make it possible to reproduce all records with a single response adjustment and we care very little what the recordist does in order to enable him to produce a satisfactory result. The Audio Engineering Society proposal is an unusually happy one and has already been found very satisfactory even so early in its life.

The *Comité Consultatif International des Radiocommunications* has recently proposed a recording characteristic for European discs which is a very close counterpart of the Audio Engineering Society proposal; in fact, each curve is within the tolerance of the other. As a result it is feasible to look for world-wide standardization in the future.

In disc recording, signals are recorded as lateral or vertical undulations in a groove, whereas in magnetic recording they appear as varying degrees of magnetization along the length of a strip of suitable material. The two methods are of almost equal age, for Valdemar Poulsen in Denmark worked with magnetic recording late in the last century. A useful technique for reducing the distortion and noise of a modern magnetic recording was invented by Carlson of the United States Navy in 1921. He applied an inaudible high-frequency voltage of constant amplitude to the recording head simultaneously with the signal to be recorded. The exact mechanism by which the improvement results is not rigorously agreed on, but there is no doubt that without such alternating-current bias technique, magnetic recording would not enjoy the benefits of its present wide acceptance.

Good quality sound recording is presently generally done on a magnetic tape rather than on a wire, for the latter suffers from the fatal paradox of being too thin for adequate strength and too thick for proper recording quality. It also poses the presently insuperable metallurgical problem of attaining exact uniformity of magnetic properties from one foot to the next. American use of wire for voice recording during World War II made special wire immediately available for postwar research, but the extravagant publicity claims for wire recording in 1946 and 1947 could not be fulfilled.

(Continued on page 324)

LICENSING ARRANGEMENTS WANTED

We wish to acquire patent rights on electrical components, instruments, or accessories used in the following fields:

RADIO, RADAR, OR TELEVISION. TELEPHONE, TELEGRAPH, TELETYPE, OR SOUND ON FILM. PUBLIC UTILITIES. AIRCRAFT.

Our preference is for items that have limited rather than mass markets. We have a particular interest in switches and relays, also in telephone parts and accessories.

All replies to be held confidential. Please write to Box G Technology Review. SA-3

ME...
an AIRCRAFT engineer?

But I haven't majored in aeronautical engineering

That doesn't matter. Lockheed can train you... at full pay!

It's your aptitude, your knowledge of engineering principles, your degree in engineering that count.

Those—plus the opportunity Lockheed is offering you—are all you need for a career as an aircraft engineer. In Lockheed's special program for engineering graduates, you may go back to school, or you may convert to aircraft work by doing—on-the-job training. But whichever it is, you receive full pay while learning.

But Lockheed offers you more than a career. It offers you a new life, in an area where living conditions are beyond compare. Outdoor living prevails the year-'round. Mountains, beaches are an hour from Lockheed.

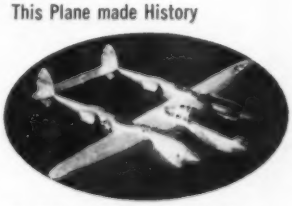
See your Placement Officer today for the details on Lockheed's Aircraft Training Program for engineers, as well as the better living conditions in Southern California.

If your Placement Officer is out of the illustrated brochures describing living and working conditions at Lockheed, write M. V. Mattson, Employment Manager

Lockheed Aircraft Corporation

Burbank, California

This Plane made History



The P-38 Lightning – first 400 mile per hour fighter-interceptor, the "fork-tailed Devil" that helped win World War II.

This Plane is making History

The Super Constellation – larger, faster, more powerful; the plane that bridges the gap between modern air transport and commercial jet transport.

This Plane will make History

This plane – which exists only in the brain of an engineer like yourself – is one reason there's a better future for you at Lockheed. For Lockheed will always need engineers with ideas, engineers with imagination, engineers who build the planes that make history.

ALL WOOL CHEVIOT
FOR RAIN OR SHINE

You have to see Rogers Peet's famous Scotch Mist* Topcoat to believe that such a coat can really be. It's as fair to the eye as the finest day of Spring . . . yet ready for the wettest! Keeps you spick-and-span in every kind of topcoat-weather . . . and bone-dry when it rains!

Tailored here in our own workrooms from our all-wool Scotch Mist Cheviots . . . in a wonderful choice of weaves and colors . . . woven after our rain-proof formula in Scotland. Two-Coats-in-one.

$95.

*Trademark Reg. U. S. Pat. Off.

Rogers Peet Company
Makers of fine clothes

In New York: Fifth Ave. *at* 41st St.
Thirteenth Street *at* Broadway
Warren Street *at* Broadway
And in Boston: Tremont St. *at* Bromfield St.

AUDIO ENGINEERING

(Continued from page 322)

Postwar study of German wartime recording showed that they had rediscovered the alternating-current bias technique before we had, and that they had solved the quality-strength paradox by using a very thin layer of magnetic iron oxide on a non-magnetic plastic base of adequate thickness for strength. They simultaneously solved the problem of uniformity by making the oxide in large batches and mixing thoroughly before coating. Thus the material on one foot became an exact counterpart of that on the next, and only mechanical uniformity of thickness was necessary.

Intensive American research has developed oxides which are far superior to the German, as evidenced particularly by the improvement in frequency response. A good index to this is the available frequency range per inch of tape speed; the Germans achieved 330 cycles per second per inch per second, whereas we have already exceeded 2,000 cycles per second per inch per second. In doing this we have also improved the other index to performance, signal-to-noise ratio.

Even at 2,000 cycles per second per inch per second, a tape speed of seven and a half inches per second is needed to match the frequency range which discs provide, and the cost is rather high for home use. To overcome this, many home tapes are recorded with two tracks: the initial track is recorded along one edge; when the end is reached, the tape travel is reversed and the second track is recorded along the other edge of the coating. This halves the tape cost per minute of recorded sound, and the resulting loss in signal-to-noise ratio has proven too small to be objectionable. The same multiple track philosophy has been used in the intermediate-storage tape element used in digital computers, but many more tracks may be used.

Better Home Recording

High-quality home recording on lacquer discs was thoroughly possible in 1940, but the cost and mechanical skill required kept many from obtaining good results. Some very low-cost, home-recording equipment was available, but quality of result therefrom was so poor as to hinder sustained use.

(Continued on page 326)

William H. Coburn, '11 William F. Dean, '17

William H. Coburn & Co.

INVESTMENT COUNSEL

68 Devonshire St. Boston, Mass.

BANKING FOR **modern** NEW ENGLAND

Electronics

BACKED BY BASIC PRINCIPLES

Imagination, alertness, and a thorough groundwork of basic principles have a lot to do with New England's reputation for developing successful electronic devices.

Such qualities are essential in banking, too. When you bring your financial problems to us, you tap a reservoir of banking experience. You also benefit from our alert understanding of the economic changes which today may affect your business.

Why not come in and let us help you develop your opportunities?

The

New England Trust Company

135 DEVONSHIRE STREET

At the Corner of Milk Street

BACK BAY BRANCH : : 99 NEWBURY STREET

Boston, Mass.

Established 1869

Member Federal Deposit Insurance Corporation

39.95 to 79.50

SUITS . . . . .

worsteds
sharkskins
.....here are suits that are built to withstand hard wear, keep their press and retain a like-new appearance. Choice of blue, gray or brown.

flannels
.....both imported and domestic fabrics are available in light, medium or dark shades of gray. Tailored with the natural shoulder.

gabardines
couriers
.....These fabrics will never lose their popularity. They are suitable for year round wear and have many fine tailoring features.

The COOP
Harvard Square Store

39.95 to 77.50

TOPCOATS

tweeds
.....These topcoats are the full cut models, roomy, comfortable and warm but light on the shoulders. Lined or unlined.

gabardines
.....all wool fabrics of excellent quality. Fine tailoring is a feature. Set-in sleeves and slash pockets. Lined or unlined.

coverts
.....a Venetian fabric so woven that it provides extra long wear. Natural tan shade. Zipper lined, including the sleeves. A reliable coat in all sorts of weather.

The COOP
Harvard Square Store

AUDIO ENGINEERING

(Continued from page 324)

During World War II, American interest in magnetic recording led to the development of some extremely portable and relatively inexpensive wire recorders of poor sound quality. At the end of the war, improved wire was developed, and home wire recorders of adequate quality became available from many manufacturers. When magnetic tape became available, most engineering was concentrated on tape recorders, and so nearly all types of home machines made today use that recording medium.

The magnetic tape offers the user a record of adequate quality and fair compactness which may easily play as long as an hour. Thus we have the prospect of pre-recorded tape for the home, of particular interest in the field of classical music. If the tape is to compete generally with the disc, it must master the problem of mass duplication at minimum cost and with virtually no loss of quality of the original. The problem has resisted solution, for two reasons:

1. Whereas an hour of recording may be duplicated in less than a minute by pressing a disc, the re-recording of an hour of program material on tape, with even moderately presentable quality, at present takes at least a quarter hour, for it must be done foot by foot.

2. Whereas disc-pressing stock forms only a small part of the total cost of discs, tape cost is a considerable fraction of the cost of a pre-recorded tape. This could be reduced if there were general public acceptance for low-quality tape, for then lower cost material could be used. But, the public has shown very little interest in tape of substandard quality.

Someone has jokingly said that the cost for duplicating tape is proportional to the cube of the desired quality of sound. If this remains even partially true, then tape will price itself out of the home market, and the development of still longer-playing discs will be required. The present 10- and 12-inch long-playing discs do not represent the limit of what is feasible of achievement. For example, in 1948 the writer suggested that 50-minute recordings could be put on each side of a 16-inch disc, or 36-minute programs might be recorded on each side of a 13¼-inch disc.

(Continued on page 328)

THE MURRAY PRINTING COMPANY

A Complete Printing Organization
Specializing in Book Reproduction

Wakefield • Massachusetts

THE ORIGINAL SWING BOOM MOBILE CRANE WITH FRONT-WHEEL DRIVE AND REAR-WHEEL STEER

KRANE KAR

MOVES LOADS EASIER - FASTER - SLASHES COST OF MATERIALS HANDLING

KRANE KAR handles loads at Sides as well as at Front.

Gas or Diesel. Pneumatic or solid rubber tires; 9 to 37 ft. booms or adjustable telescopic booms; electric magnet, clamshell bucket, and other accessories available.

At your service 24 hours every day because it is gasoline-powered (no layups for battery charging). Works inside and outside your plant. KRANE KAR serves also as an auxiliary to existing crane facilities . . . and as an emergency tool for plant maintenance. Let us show you. Ask for Bulletin No. 79 or for a Sales-Engineer.

1½, 2½, 5 and 10 ton capacities.

SILENT HOIST & CRANE CO.

891 63rd ST., BROOKLYN 20, N. Y.

If You Need Additional Manufacturing Capacity

CALL IN

LIQUID's

CONTRACT MANUFACTURING DIVISION

Capacity and manpower available on Machine Shop, Sheet Metal and Woodworking facilities for industrial or defense contracts.

Write for illustrated booklet "Special Contract Department" which lists and describes facilities.

Liquid Contract Manufacturing Division

THE LIQUID CARBONIC CORPORATION

3100 South Kedzie Ave. • Chicago 23, Illinois

Manufacturers of Brewing and Bottling Machinery, Soda Fountains, Gas Welding Equipment, CO_2 Gas, Dry Ice, Oxygen and Medical Gases

CHECK WITH RAYTHEON for Special Purpose TUBES

- ☐ Aircraft Control
- ☐ Electrometer and GM
- ☐ Germanium Diodes and Triodes
- ☐ Guided Missile
- ☐ Hearing Aid
- ☐ Long Life Industrial
- ☐ Ruggedized
- ☐ Special Purpose
- ☐ Subminiatures of all kinds

Raytheon has designed and produced millions of such tubes — has the specialized technical skill and resources to meet your needs. Over half a million Raytheon Subminiatures are carried in stock. Over 300 Raytheon Special Purpose Tube Distributors are ready to serve you. Application engineering service at Newton, Chicago and Los Angeles.

RAYTHEON

RAYTHEON MANUFACTURING COMPANY

Special Tube Section

55 Chapel St., Newton, Massachusetts

A Report

TO M.I.T. MEN

In 1917 Walker Memorial Building was opened, a gift from Alumni for the welfare of M.I.T. students. In addition to including offices for student activities and serving as a student social center, this building houses the dining service.

In 1950–51 nearly one million meals were served to staff and students and 57 dances, receptions and balls were held in Morss Hall. Morss Hall seats approximately 500 people. Thus, each chair served 2,000 people per year or 5.5 persons per day. We thank the Alumni for making these services possible.

WALKER MEMORIAL DINING SERVICE

• M.I.T. •

CAMBRIDGE 39, MASSACHUSETTS

A. W. BRIDGES, *Manager*

RUBBER
Parts and Products

Acushnet
PROCESS COMPANY
NEW BEDFORD, MASS., U. S. A.

We have complete modern equipment and specialized engineering skill to precision-mold mechanical rubber parts or products to your specifications.

Address all correspondence to 774 Belleville Ave., New Bedford, Mass.

Rate Measuring
GYROSCOPES
for
Control
Stabilization
Flight Testing
Rate Computation
For the accurate measurement of absolute rates of angular rotation, the Doelcam Model K Rate Measuring Gyroscope offers the following features:
1. Accuracy: 0.5%
2. Resolution: 0.1%
3. Maximum uncertainty: 0.2%
4. Hermetically sealed
5. Shock and vibration resistant
6. Microsyn pickoff: 60 — 5,000 cps
7. Thermostatically controlled damping ratio
8. Small size: 3 inches diameter x 5.82 inches
9. Lightweight: 3 5/8 lbs.
The design of the Model K Gyroscope affords wide latitude in the adjustment of parameters and permits design to any particular specifications.
DOELCAM CORPORATION
56 Elmwood Street Newton 58, Massachusetts
GYROSCOPIC FLIGHT TEST AND CONTROL INSTRUMENTATION
SYNCHROS · SERVOMECHANISMS · MICROSYNS
ELECTRONIC INVERTERS

AUDIO ENGINEERING

(Continued from page 326)

Present Status of Magnetic Tape Recording

Magnetic tape has invaded so many fields that it has become difficult to keep track of all new applications. Everyone knows of its use in home recording, in the broadcast station, and the recording studio, but these form only a part of the field today.

Educational applications have multiplied rapidly. Starting with equipment of rather poor quality, there has been steady upgrading, and today much equipment (particularly in the colleges) is fully professional in quality. Within the last few years it has been realized that the quality of professional equipment is essential for many educational applications, particularly speech correction, drama, and music, even for practice at home.

To Save Some Correspondence

An extended discussion of technical details of sound-reproducing equipment for use in the home would be out of place in the pages of The Review. Nevertheless the audio hobbyist always seems to crave advice. There are two places not to get this advice, and one place to secure it.

First of all, do not ask your friend, the recent graduate of the communication option in electrical engineering. He has suffered from a mixture of a rarefied brand of acoustical physics and a semivocational course in radio engineering. If he knows anything about making reproduced music sound better, it is strictly fortuitous. Secondly, do not ask this writer. Advice that does not satisfy the reader's aural taste is likely to do more harm than good, for there is no real way of transmitting aural preference by letter.

If you insist on spending your hard-earned money on home-music reproduction, the best method of choosing equipment is by listening tests in which you are the active participant. Most radio parts jobbers can set up, and select by means of push buttons, the various combinations of audio equipment which lie within your budget limits. A few minutes of critical listening to the different combinations should make one's preferences apparent. A somewhat longer listening period is preferable if your ear is poorly

(Concluded on page 330)

LEONARD CONSTRUCTION COMPANY

Engineers and Contractors

SINCE 1905

IN THE AMERICAS AND FAR EAST

37 South Wabash Ave.

Chicago

SCULLY SIGNAL COMPANY

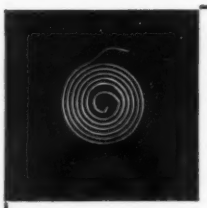
Safe Fills } with VENTALARM®
No Spills } WHISTLING TANK FILL SIGNAL

for automotive, home and diesel fuel tanks

F. P. Scully '15

88 First St., Cambridge 41, Mass.

"JUST FILL 'TIL THE WHISTLE STOPS"



PRECISION-GAUGED HAIRSPRINGS AND FINE ROLLED WIRE

PRECISION PRODUCTS COMPANY

WALTHAM, MASSACHUSETTS

ROBERT I. BRADLEY, '20

D. M. DILLON STEAM BOILER WORKS

Incorporated

BOILER and STEEL FABRICATION

FRED N. DILLON, JR. 1922
PRESIDENT

FITCHBURG, MASS.

HAROLD J. RYAN, INC.

Air Conditioning

101 PARK AVENUE

NEW YORK 17, N. Y.

The TREDENNICK-BILLINGS CO.

Construction Managers — *Building Construction*

K. W. RICHARDS '07 — H. D. BILLINGS '10 — C. C. JONES '12 — F. J. CONTI '84

10 HIGH STREET

BOSTON, MASSACHUSETTS

SYSKA & HENNESSY, INC.
Engineers

DESIGN • CONSULTATION • REPORTS
POWER PLANT • WASTE DISPOSAL • WATER SYSTEMS
New York City

HOLMES & NARVER, INC.

ENGINEERS • CONSTRUCTORS
828 SOUTH FIGUEROA STREET
LOS ANGELES 17
TRINITY 8201

JAMES T. HOLMES
M.I.T. '14

D. LEE NARVER
STANFORD '14

N. A. LOUGEE & COMPANY
ENGINEERS AND CONSULTANTS

Reports—Appraisals—Depreciation Studies
Rate Cases—Business and Economic Studies

120 BROADWAY NEW YORK 5, N.Y.
N. A. LOUGEE '11 L. A. MATTHEWS '13
J. W. McDONALD, Jr. '20 R. F. THOMAS, Jr. '13
E. S. WEST '40

CHARLES N. DEBES
AND ASSOCIATES
Engineers and Consultants
Plans, Specifications, Construction Supervision
Industrial Plant and Commercial Projects
Electrical — Mechanical — Sanitary — Structural
ROCKFORD TRUST BLDG. ROCKFORD, ILL.
C. N. DEBES '35

AUDIO ENGINEERING

(Concluded from page 328)

trained, for certain fatigue effects take time to assert themselves to the untrained ear.

As in so many other fields, the results obtained depend on the money spent (which lies anywhere between $100 and at least $2,000). The pursuit of the ultimate is long, and the law of diminishing returns operates early. Nevertheless, it is safe to say that a mass-produced set, yielding even moderately high-quality results, will cost three to five times as much as a high-quality system bought from the jobber. For the very ultimate in results, no mass-produced set is available at all at present. Your jobber can supply a wiring sketch and a set of connecting wires cut to length and ready for use. Many will take care of adapting your own cabinet to the equipment if you wish, but you must do the installation yourself.

For 20 years it has been conventional to examine anything new for its social significance, and so perhaps we should examine audio. The most amusing thing is that the high-quality field seems to exist only on this side of the iron curtain; apparently it is very difficult to make good phonograph records behind the iron curtain. In fact, no one there has even claimed to have invented the record — an unfortunate omission for which someone will suffer.

More seriously, we have a widespread interest comparable only to the interest in radio in the 1920's, and leading similarly to widespread study of electronics as a hobby. In the 1920's this led to the introduction of a communications option in many electrical engineering courses. Now we see some student pressure for a reorientation of these courses, and more attention to the audio aspects of electronic engineering. In most cases this pressure has produced little result, and the commercial institutes have had to fill the gap.

LESSELLS AND ASSOCIATES, INC.—ENGINEERS
RESEARCH — DEVELOPMENT — TESTING — CONSULTATION

Mechanical Design and Development
Analysis and Prevention of Mechanical Failures
Experimental Stress Analysis
Laboratory and Field Test Facilities

916 Commonwealth Avenue, Boston 15, Mass.
Telephone BEacon 2-2380
P. E. Kyle '39 T. A. Hewson '45 C. H. Kano '43 R. F. Bredrick '48

PREPARATORY SCHOOLS FOR BOYS

CHAUNCY HALL SCHOOL
Founded 1828. The School that specializes in the preparation of students for the Massachusetts Institute of Technology.
Ray D. Farnsworth, *Principal* 533 Boylston Street, *Boston, Mass.*

HUNTINGTON SCHOOL FOR BOYS
Grades Eight to Twelve.
Thorough preparation of entrance to M.I.T.
Regular and Summer courses.
Excellent facilities for athletic & other activities.
William G. Wilkinson, Headmaster
320 Huntington Ave., Boston Tel. Kenmore 6-1300

PROFESSIONAL CARDS

JACKSON & MORELAND
Engineers and Consultants

Design and Supervision of Construction
Reports — Examinations — Appraisals
Machine design — Technical Publications

BOSTON NEW YORK

JOHN W. NICKERSON '09
MANAGEMENT ENGINEER

Advice on
LABOR RELATIONS ∽ WAGE INCENTIVES
JOB EVALUATION ∽ MERIT RATING

46 Mt. View Dr., W. Hartford, Ct. Tel. 32-6665
Niantic, Ct. Tel. 9-5933

EADIE, FREUND AND CAMPBELL
CONSULTING ENGINEERS

500 FIFTH AVENUE NEW YORK 36, N. Y.

Mechanical — Electrical — Sanitary
Air Conditioning — Power — Process Layouts

J. K. Campbell, M.I.T. '11

STARKWEATHER ENGINEERING CO.
INCORPORATED

Engineers and Contractors for Pumping Plants
Boiler and Power Plants, Cooling Water
and Heat Recovery Systems

246 Walnut Street, Newtonville BI 4-8042

J. B. Starkweather, B.S. M.I.T. '21

THE KULJIAN CORPORATION
1200 North Broad St., Philadelphia 21, Pa.
CONSULTANTS—ENGINEERS—CONSTRUCTORS
Specialists in
UTILITY, INDUSTRIAL, AND CHEMICAL FIELDS
Offices in
Washington, D.C.—Mexico City, Mexico—Rome, Italy
Calcutta, India—Caracas, Venezuela—Tokyo, Japan
Madrid, Spain

H. A. KULJIAN, '19 A. H. KULJIAN, '48

FABRIC RESEARCH LABORATORIES
Incorporated

Research, Development and Consultation
for Textile and Allied Industries

665 Boylston Street Boston, Mass.

W. J. HAMBURGER, '21 K. R. FOX, '40 E. R. KASWELL, '39

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS

Malcolm G. Davis '25, *Vice President* Allen W. Reid '12 E. C. Edgar '35

Steam, Hydro, Diesel Power Plants; Industrial Structures; Plant Safety, Labor Relations, Utility Rates, Valuations, Reports; Large Scale Purchasing; Industrial Laboratory

New York, N. Y. Reading, Pa. Washington, D. C.
Philadelphia, Pa. Houston, Tex.

FAY, SPOFFORD & THORNDIKE
Engineers

Airports — Bridges — Water Supply and Sewerage
Port and Terminal Works — Fire Prevention

INVESTIGATIONS DESIGNS
SUPERVISION OF CONSTRUCTION

Boston New York

CLEVERDON, VARNEY & PIKE
Consulting Engineers

HERBERT S. CLEVERDON '10 WALDO F. PIKE '15
LAWRENCE J. TRACY '23

Structural Designs Foundations
Heating Ventilating and Plumbing Designs
Industrial Buildings, Reports, Investigations

120 TREMONT STREET BOSTON 8, MASS.

MAURICE A. REIDY
Consulting Engineer

BRIDGES BUILDINGS
STRUCTURAL DESIGNS FOUNDATIONS
CONSTRUCTION CONSULTANT AND ARCHITECTURAL ENGINEER

Estimates and Appraisals

101 TREMONT STREET BOSTON, MASS.

SERVO CORPORATION OF AMERICA
Henry Blackstone '37, President

Consultants on
Electronic Control Problems
for Industry

New Hyde Park Long Island, N.Y.

MORAN, PROCTOR, MUESER & RUTLEDGE
CONSULTING ENGINEERS

Foundations for Buildings, Bridges and Dams;
Tunnels, Bulkheads, Marine Structures, Soil Studies and Tests; Reports, Design and Supervision

Pardo, Proctor, Freeman & Mueser
Ingenieros Consultores
Ap. Correos 614, Caracas, Venezuela

WILLIAM H. MUESER '22
PHILIP C. RUTLEDGE '33

CHARLES A. MAGUIRE & ASSOCIATES
ENGINEERS

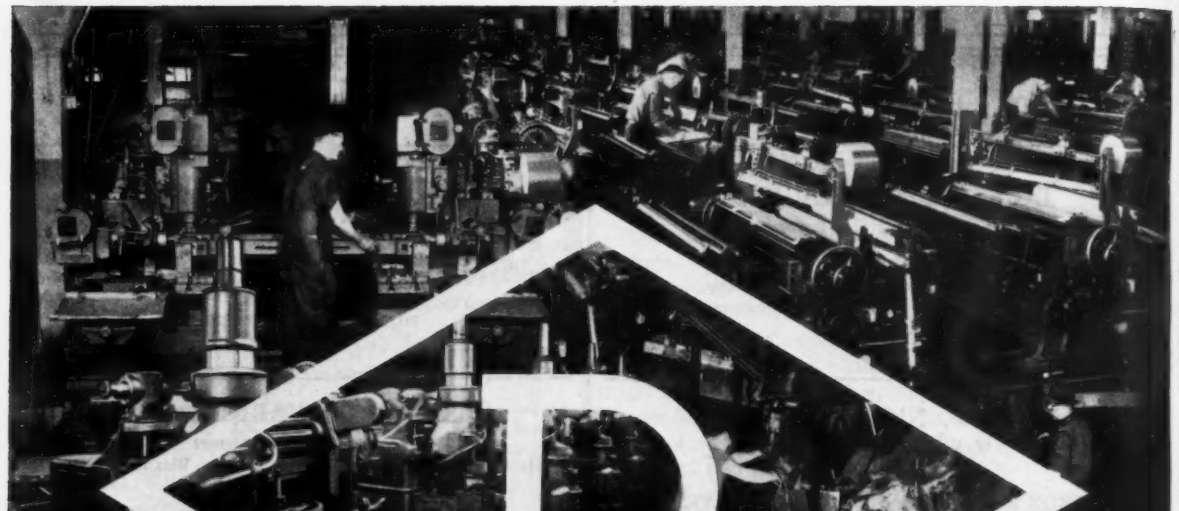
BOSTON PROVIDENCE NEW YORK

Braintree 2-2933 Hingham 6-2360

FRANK MASSA
Electro-Acoustic Consultant

99 Cedar Street
Braintree, Massachusetts

5 Fottler Road
Hingham, Massachusetts



Behind the Diamond "D" . . .

Production facilities are always changing, always improving behind the "Diamond D" — trade mark of Draper Corporation, the world's largest manufacturer of automatic looms.

New foundry techniques, better machine tools, improved methods of manufacturing are constantly being installed to insure that Draper remains one of the most progressive and modern manufacturing companies in the country.

In the last few years many millions of dollars have been expended for new equipment to give greater precision in loom parts and greater plant capacity for increased production.

Draper Looms Produce More Cloth at Less Cost Throughout the World.

DRAPER CORPORATION

ATLANTA, GA. HOPEDALE, MASS. SPARTANBURG, S. C.

What GENERAL ELECTRIC People Are Saying

H. H. WATSON

Construction Materials Division

HIGHER VOLTAGE BRANCH CIRCUITS FOR COMMERCIAL BUILDING LIGHTING: The ever-increasing trend toward higher levels of illumination in office buildings has for some time invited the use of higher voltage branch circuits. But it was not until the remote control wiring system was introduced that higher voltage branch circuits became practicable here. The Underwriters' Laboratories, Inc., standard for snap switches recognizes two voltage classifications: 0 to 250, and 250 to 600. Snap switches made to the 600-volt rating are much too large and costly to be used for the control of individual office lighting. The remote control system uses an electro-magnetic relay for switching which is built to the Underwriters' Laboratories, Inc., 0-300-volt specifications for magnetic switches. It is, therefore, properly rated for use in the 277-volt circuits of a 480Y/277-volt branch circuit system. With this new switching means available, the problem of a switch is solved. Not only is the problem solved, but the resulting system has the added safety factor of 24-volt control circuits.

Western New England Chapter I.A.E.I.
December 5, 1951

★

A. D. MARSHALL

Corporate Affairs Department

SOCIAL SECURITY—A PROBLEM FOR AMERICAN BUSINESS: A recent report by the Chamber of Commerce of the United States estimates that 300 welfare plans take a third of all government tax dollars.—$22,800,000,000 during the fiscal year of 1949-50—or $575 for every tax-paying family.

Over the years the leaders of our business enterprises have solved many problems through their own individual initiative. They have made more products available at less cost to the American worker than any nation in the history of the world. But we are now confronted with the fundamental problem of whether American business can face and solve, through the initiative of its managers and businessmen, the problems involved in social security, or whether these are to be taken over by bureaucratic government control and resolved in a way which will lead us directly from social security into socialism. There appears to be little doubt that when a government takes over the savings of all the people for the emergencies of life—sickness, death of the breadwinner, unemployment, old age, and the many other things which the social planners include in the so-called social security program—and directs to whom and under what circumstances that money shall be paid, the government which does that must soon take the responsibility of directing the lives and actions of all of us.

Many social planners and government bureaucrats see in the desire for individual security an opportunity for more and more government control. This may be one form of security, but most of you people will agree with me that real security lies in the productive success of the enterprise with which we as individuals are connected.

We should not let the battle go to the social planners by default. We must spend time and effort in analyzing and presenting the necessary facts to our legislators with respect to these problems and, more than that, we must present the solutions which will not only meet the problem, but will also serve to fit into our concept of the free enterprise system.

Annual Meeting,
Framingham Chamber of Commerce
January 15, 1952

E. D. TROUT

X-Ray Department

COBALT-60 IRRADIATOR FOR TELETHERAPY: In 1951, a Cobalt-60 unit was constructed by General Electric to the basic design of L. G. Grimmett, Ph.D, Head of the Department of Physics of the M. D. Anderson Hospital for Cancer Research at Houston, Texas.

The Cobalt-60 irradiator has now been installed at the Oak Ridge Institute of Nuclear Studies and it has been loaded with a 200 curie source loaned by Dr. Max Cutler of the Chicago Tumor Institute. A preliminary report on the irradiator was presented before the Radiological Society of North America at its recent annual meeting. Further studies of the shielding about the source, beam characteristics, and depth dose are underway, as are biological studies. When these are completed the irradiator will be reloaded with a 1000 curie (effective) source from the Chalk River pile and transferred to the M. D. Anderson Hospital for use in the treatment of cancer.

The 1000 curie source should deliver approximately 90 roentgens per minute at the end of the 50 cm. treatment cones. An x-ray generator operating at 1 mv. and 3 ma. produces 150 roentgens per minute, and a 2mv. x-ray unit operating at 1.5 ma. delivers 600 roentgens at this distance. The Cobalt-60 beam, being nearly monochromatic at 1.2 mev. should be more nearly comparable to the 2 mv. x-ray unit in the matter of depth dose.

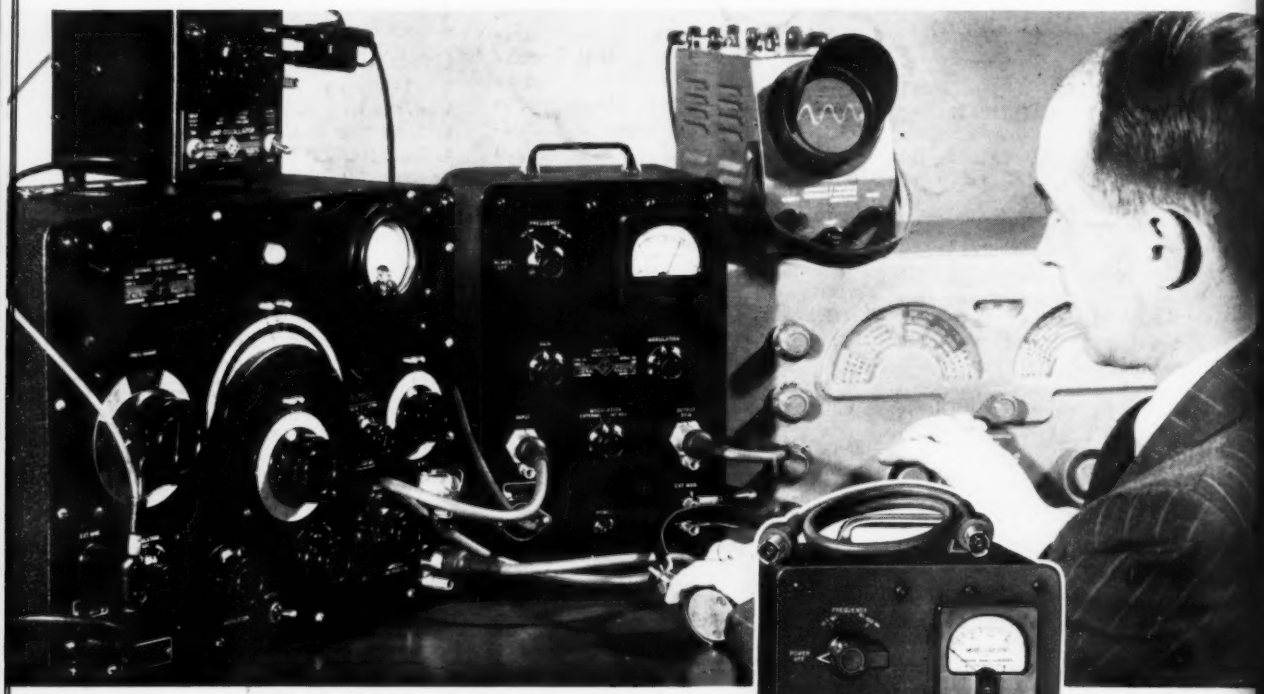
Until such time as Cobalt-60 becomes available at a much lower cost, or until some other artificial source becomes available, the supervoltage x-ray machine will not be supplanted by artificial radioactive substances.

AIEE, New York City
January 7-8, 1952

You can put your confidence in—

GENERAL ELECTRIC

Here's a Simple Way to Eliminate Incidental FM from A-M Measurements on HF and UHF Equipment



Carrier Range: 5 to 220 Mc

Modulation Frequency: 20 to 15,000 Cycles

Type 1023-A Amplitude Modulator
$250

The GR **Type 1023-A Amplitude Modulator** provides an a-m signal with no significant fm, from all standard-signal generators. All simple standard-signal generators, even those with a modulated amplifier following the oscillator, provide some incidental fm when amplitude modulation is used. This effect is particularly prevalent above 30 Mc. The presence of incidental fm can produce completely false results in measurements of both selectivity and sensitivity.

With many a-m signal generators incidental fm may be as high as 20 kc at 50 Mc with 80 to 100% modulation. Use of the G-R Type 1023-A Amplitude Modulator will result in an improvement of as much as 1000 to 1.

This instrument is particularly useful in checking the performance of such apparatus as voice ground-to-air communication equipment; air navigation Omnirange and ILS; telemetering and remote control equipment using am.

It provides a means of adding am, without incidental fm, to f-m signal generators so that simultaneous measurements of a-m rejection and f-m response can be made on equipment used in such services, as fm, tv, telemetering and remote control.

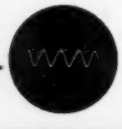
It also makes an unmodulated test oscillator into a modulated signal source, free from fm.

One of its important features is a second range of 10.1 to 11.3 Mc. At 10.7 Mc (the RMTA standard f-m receiver intermediate frequency) this range provides a gain of 10 with a bandwidth to the half-power points of ±0.6 Mc, gain and modulation percentage being substantially independent of input voltage at levels up to 0.1 volt. Output voltages up to 3 volts can be obtained without serious increase in envelope distortion, with some change in gain.

Modulation up to 80% is provided, either internal at power-line frequency or external from 20 to 15,000 cycles. Envelope distortion is less than 5% at 80% modulation. From 1 microvolt to 1.5 volts, gain and modulation percentage are practically independent of r-f input voltage.

Oscilloscope Traces

Audio output of receiver (without crystal or other band rejection circuit) when normal incidental fm is present in signal source. Carrier frequency 50 Mc; modulating frequency 400 cycles.



Audio output of same receiver with same signal generator when a Type 1023-A Amplitude Modulator is used to avoid any incidental fm. Same carrier and modulating frequencies.

GR®

GENERAL RADIO Company

275 Massachusetts Avenue, Cambridge 39, Massachusetts

90 West Street NEW YORK 6 920 S. Michigan Ave. CHICAGO 5 1000 N. Seward St. LOS ANGELES 38